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Grinding and sharpening blades on the mill stones.

THE CUTLERS OF THIERS.—[See page 184.]

Modern Ideas on the End of the World*

New Contributions to Cosmology Obtained from the Development of Differential Theories

By Gustav Jaumann, Professor of Physics at the Technical High School at Brunn

We are totally ignorant of the beginning of the world. During the last century the hypothesis of Laplace and Kant that the planets proceeded from the sun and were cast off by the rotation of it enjoyed wide credence. According to this theory our earth was once in a state of glowing liquid. Judging by the increase in temperature in the deep strata, it is covered at the present time by the solidified crust, relatively very thin, on which we live. Such a conception has rendered plausible a belief in the deluge and in the idea of a final day of judgment when the world will be devoured by flames.

Geology, indeed, records horrible catastrophes: the highest mountains were formed by a single short earthquake of tremendous violence, the result of upheavals of granitic magma. By enormous volcanic eruptions erratic blocks were carried thousands of kilometers. In particular the whole of Asia suffered the invasion of the Indian Ocean, which was precipitated on the continent with inconceivable violence, sufficient to carry the rhinoceros and the mammoth, which are considered Indian animals, as far as the frozen fields of Siberia. Cuvier affirmed not only that the world would be destroyed some thousands of years hence, but that it has already many times undergone like cataclysms, each geologic formation constituting the burial place of a creation entirely separate in origin. According to this hypothesis, the termination of each geologic period has been marked by a complete ending of the world, and the opening of each succeeding period by a special creative act giving birth to a new fauna more perfect but equally incapable of evolution. By the side of the brilliant Cuvier lived, obscure and unknown, the much greater Lamarck. It is he who recognized the continuous evolution of the faunas in accordance with an immanent law, or at least in consequence of the capacity which organisms possess of perfecting themselves by assiduous exercise and by communicating in part to their descendants the improvements thus acquired. It is this way of thinking which, after a turn toward Darwinism,[1] has finally established itself. Now, to permit such an evolution of the organic world, from the beginnings to its actual perfection, requires a considerable duration of cosmic quiet. Geologic investigations since Lyell have indeed demonstrated that the passage from each geologic formation to that succeeding it is made gradually and without interruption. The inundations and volcanic catastrophes which are produced at all times, far from destroying worlds, have never been more than purely local. Volcanic eruptions are not the index of a fluid and incandescent nucleus, for the accumulations of liquid lava have little extension, so that even neighboring volcanoes, such as Vulcano and Stromboli, have no relation to each other. One can even affirm that the fluid incandescent nucleus of the earth does not exist. Recent physical observations, especially those relative to the transmission of the transverse seismical waves through the interior of the earth and to the period of migration of the terrestrial axis, admit of the conclusion that the earth in its entire mass is as elastic as a steel of good quality.

But now we must observe the very disquieting previsions of the exact sciences. These we must notice particularly, for physics and astronomy have exact natural laws, and in this way may be predicted in all probability the most distant consequences, for the laws which are concerned here, that of gravitation and that of the conservation of energy, are among the ones most firmly established.

The real achievement of Newton was to show that the law of gravitation had a more exact application than the laws of Kepler according to which the planets move along their elliptical orbits.[2] In reality the planets do not describe strictly elliptical trajectories. The form and the position of these trajectories change constantly, although with extreme slowness. The law of Newton affords an explanation of the greater part of these divergences, if the reciprocal attractions of the planets are taken into consideration. Taking these deviations into consideration, it is possible at present to calculate to within a few seconds the positions of the sun, the moon, and the planets a hundred years in advance. But to determine at a distance of millions of years the end of the Newtonian world enormous mathematical difficulties must be overcome; indeed, it is a matter concerning the problem of the stability of the planetary system and of calculating whether the disturbing influences, weak but incessant, which the planets exercise upon each other will nearly counteract each other in time or will end by entailing the destruction of the planetary system.

Eminent scholars have always taxed themselves with resolving this fundamental problem relative to the stability of the world. Laplace and Lagrange showed, by means of an approximate calculation, that the planetary system of Newton appeared to be stable. Poisson demonstrated that by further refining the calculation later epochs could be surveyed, in which greater and greater fluctuations in the form of the planetary orbits were present. Finally Poincaré proved that by carrying the calculation to its limit, a future time was disclosed in which the planets would experience unlimited, progressive, so-called secular disturbances and, finally, some of them would fall into the sun, and others lose themselves in the cold of cosmic space. Thus, the planetary system of Newton has no stability, no internal constancy. But the foregoing calculations were made on much too favorable a basis. Cosmic space can not be empty, as Newton held. Since it can transmit light, it must be filled with a medium, extremely tenuous and cold, called cosmic ether. The extreme vacuum obtained in the laboratory, cooled to —170 deg. Cent., presents a considerable viscosity, which is only ten times inferior to that of the normal air.[3] Consequently, the cosmic ether must oppose to the movement of the planets a very appreciable frictional resistance. They must continually lose energy of motion; in addition to which, the attractive action of the sun becoming more and more considerable, the planets should describe orbits more and more narrow and should end, in some millions of years, by precipitating themselves into it. Thus, again, we have the "igneous" death of the earth. But that end would be preceded by the destruction of the terrestrial organisms, all being menaced by death from the cold, which would set in much earlier.

The energy thrown out with the sunlight is several billion times greater than the total interchange of energy which takes place on the earth. The sun gives off continually enormous quantities of it, and its supply, of whatever unknown kind it may be, must finally be exhausted. It would cool down more and more, and our civilization, after terrible struggles, would meet with disaster more and more amidst the ever-present ice.

Thus the two fundamental physical laws lead, it is seen, to essentially gloomy consequences, but, with all the respect that is due to their sublime results and to their precision, it is only right to ask whether they are really established with such ideal exactness as to enable one to draw conclusions applicable to epochs immensely remote, and to comprehend the very plan of creation. Before accepting these consequences it will be well to submit these inexorable laws to a much more searching scrutiny. That the law of gravitation will not support an examination carried to extreme limits, nearly all astronomers agree in admitting. The most striking deviation from this law is offered us by the moon, which undergoes an inexplicable acceleration, but less than 6 seconds per century. An analogous anomaly, more marked and still more complicated, has also been recognized in the motion of Encke's comet. The orbit of Mercury presents an inexplicable perihelic rotation, attaining 40 seconds per century, and its eccentricity is not augmented with the rapidity which the law of gravitation demands. The orbit of Mars is subject to anomalies of the same nature, while the inclination of the orbit of Venus increases too rapidly by 10 seconds every century. Terrestrial gravity presents, even from the point of view of direction, a diurnal and annual oscillation of a fraction of a second, which is not to be explained alone by the attraction of the moon or of the sun.[4] It is true that these are relatively small and isolated deviations, and that in general the law of gravitation suffices for the calculation of the motions of the stars with a sufficient approximation, always assuming that the cosmic ether is absolutely devoid of friction. This latter, however, is far from being accepted by physicists. When one considers that the periodic comets, even the smallest ones, apparently undergo no frictional resistance, that they are capable of penetrating the solar corona at a speed of 5,500 kilometers per second, without undergoing appreciable loss, one is obliged to admit that the law of gravitation is not sufficient, but that forces unknown, though hinted at by Kepler, act upon the stars in motion, and tend to offset the effects due to friction of the cosmic ether. It is a fact that no trace, however slight, of a beginning of the falling of the planets toward the sun, as the law of Newton predicts, has yet been shown. The same may be said of the cooling of the sun, which should follow in accordance with the law of energy. It was supposed for a long time to be self-evident that the climate of the earth had grown constantly cooler, but this idea has been entirely abandoned. Fluctuations less than 10 deg. Cent. on both sides of the mean temperature have often occurred, several times in Europe, thus placing these regions now under tropical conditions, and now under the conditions of the Arctic Zone. But from this point of view the most remote ages of the geologic history of the earth differ not at all from the present epoch. Glacial formations, extensive but not thick, have been found in early Cambrian strata.[5] At that time the temperature was not higher but lower than in our epoch, and more than a hundred million years have passed since then.

One can with difficulty admit of the existence in the sun of a supply of energy able to endure without appreciable decrease, for so long a time, the enormous expenditure due to radiation. The stability of the planetary system and the inexhaustible luminous power of the sun are, furthermore, to a certain extent verified by direct geologic observation.

How is it that the law of gravitation and the principle of the conservation of energy fail so entirely in their prophecy concerning the end of the world? What is the hidden defect of these laws which, as the foundations of physics, have given such magnificent results within narrower limits, and how can they be given an entirely correct form?

Regarding these really fundamental questions of theoretical physics, I feel myself called upon to speak, in so far as they fall within the field of my own studies. I should point out, however, that questions are concerned which are far from being decided, and that I can treat here only their "phenomenalistic" aspect. The Newtonian hypothesis of the attraction of a star on a remote body, directly and instantly, without the physical intervention of an intermediary medium, was an abstraction nearly accurate, though at bottom little true to nature. Laplace himself admitted the progressive transmission of gravitation.[6] He supposed that this effect was propagated, though at great speed, through the cosmic ether. The magnetic forces between two magnets were likewise supposed at first to act immediately at a distance. Faraday recognized eventually that the air or similar medium contained between the two magnets (the magnetic field), far from being

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* Inaugural address of the rector of the Imperial German Franz-Joseph Technical High School at Brunn, delivered on October 26th, 1912. Translated from the German, in the annual report of the Smithsonian Institution, published by the technical high school.

[1] In this connection we designate as Darwinism only that part of Darwin's teachings which originated with himself; not the evolution theory, which is due for the most part to Lamarck, but rather the theory of selection, according to which there could not be any evolution of the organic world without the influence of selection in connection with the struggle for existence.

[2] The law of gravitation itself was not originated by Newton, but by Kepler, whose ideas exerted a powerful influence on Hooke, Halley, and Fermat. It was first formulated mathematically by Wren, whose physical work was otherwise unimportant. Newton only contributed proof of its correctness.

Kepler originated the fundamental and extraordinary new conception "Virtutem, quae planetas movet, residere in corpore Solis" ("The power which moves the planets resides in the mass of the sun"—heading of ch. 33 in Kepler's "Astronomia Nova." See "Jo. Kepleri Opera Omnia," Frisch's edition, vol. 3, p. 300). He also originated the idea of the field of gravitation, in which the force diminishes with the distance from the sun, and the idea of universal gravitation. Had Galileo's dynamics controlled Kepler as it did Huyghens, he would not have needed half his genius to have anticipated Newton's contributions to the subject.

[3] This extreme vacuum at —170 deg. Cent. has the modulus of viscosity 2×10^{-4} c. g. s. To overcome the resistance that the ether offers to our earth would require more than 150,000,000 horse-power. Meteorites must glow in the ether if their diameter be less than 50 centimeters. As a matter of fact, a glowing meteorite has been observed at a height of some 780 kilometers (above Sinope on September 5th, 1868, reported by G. von Niessl in Verhandl. d. naturforsch. Vereines in Brünn, vol. 17, p. 316, 1879, and even in the spectrum of the comets when approaching perihelium (when their velocity is greatest) clear indications of the glowing of solid bodies have been observed.

[4] G. H. Darwin, Tides, 1898, p. 125; O. Hecker, Publications of the Royal Prussian Geodetic Institute, No. 32, 1907.

[5] Compare, for example, Walter, History of the Earth, 1908, p. 199.

[6] Laplace Mécanique céleste, vol. 4, p. 317.

different, was in a state of tension, and that the magnetic effects of one magnet on another were propagated from point to point, from one particle to the particle immediately adjoining it. It is thus that the elementary action is always produced in ultimate particles situated in the magnetic field, and its law is a differential law expressing the relation of cause and effect between the existing conditions and their causative predecessors in each ultimate particle of the space. It is from the interaction between all the ultimate particles of the magnetic field in the so-called integral that the effects at a distance result. Maxwell established the laws of effect from point to point of electromagnetism (or differential laws of the electromagnetic field), which with an admirable simplicity not only explained the electromagnetic phenomena formerly known (which the laws of effect at a distance were equally capable of doing), but did much more; they predicted, indeed, the propagation of electric vibrations through space in the form of electromagnetic rays. The luminous rays appeared thus as electromagnetic rays. Hertz obtained, with purely electromagnetic resources, electromagnetic rays of great wave length, and Marconi has utilized these same rays in wireless telegraphy. Thus it is that one of the greatest and most difficult advances in the theory, the transition from laws of effect at a distance to theories of effect from point to point, led immediately to a great technical advance.

At that time (more than 20 years ago), many physicists, Hertz and Mach in particular, recognized that the real object of the theory was to explain physical phenomena by differential laws, a task which seemed to pass much beyond the attainable, but it has been in large part satisfactorily performed,[7] since at present the law of gravitation itself can be expressed in the form of a law of effect from point to point.[8] The end sought in this connection consists in dethroning the old corpuscular and mechanical theories still so full of vigor. The list of facts brought forth by the two contending parties increases in length from year to year and the struggle between phenomenalistic investigation and mechanical investigation is waged on a field of great extent, embracing almost the entire domain of the exact sciences. The combat centers around the question of the nature of light and of the cathode rays.[9] The new theory of gravitation is only a partial victory on the extreme wing, but by virtue of it we now have exact notions regarding the manner of propagation of gravitation through the cosmic ether. The anomalies of the field of gravitation compensate each other in cosmic space, according to a law analogous to that which rules the irregularities of the distribution of temperature in a good conductor of heat. It is only for stars in repose that the Newtonian law of effects at a distance follows exactly from the differential law of gravitation.

Now, the motions of the planets produce disturbances, a kind of damming up, so to speak, of the field of gravitation in front of the moving stars, giving birth to new forces of gravitation added to the Newtonian forces. Although very small, it can be determined with precision that the most important among them has the same direction as that of the motion of the planet to which it is a stimulus. It increases with the speed of the planet and varies in inverse ratio to the distance separating it from the sun. These new forces of gravitation introduce into the planetary movements disturbances which can be calculated without difficulty, and even cause the deviations from the Newtonian law which we have mentioned above. By them are explained the anomalous perihelic rotations, accelerations, oscillations of the vertical, etc.—that is, all the phenomena of gravitation, without any being left over, which the Newtonian law of effects at a distance was incapable of doing. These new forces of gravitation moreover give to the planetary system a physical stability of unlimited duration. They keep the planetary orbits in their present form, not only in spite of the very considerable resistance due to friction of the cosmic ether, but also in spite of enormous accidental disturbances. If a disturbance of this nature (which might be due, for example, to the passage in the neighborhood of the solar system of a fixed star imbued with a very rapid motion of its own) should be produced, and modify entirely the form of the planetary orbits, the new forces of gravitation would introduce into the elements of the orbits such variations that these planetary orbits would gradually return exactly to their existing stable form. Far from becoming dangerous, the frictional resistance of the cosmic ether, on the contrary, helps essentially to make the planetary orbits stable. The greater this resistance the more considerable become the new forces of gravitation and the more obstinate the planetary orbits in conserving, in spite of all the disturbances, their stable form. Thus there can no longer be any question of the planets dropping into the sun. Far from being unstable, far from tending toward a destruction more or less remote, the planetary system is, then, established for a duration which, estimated according to the ideas of time that we are able to conceive, may be considered as eternal.

The absolute validity of the principle of the conservation of energy is incontestable, but its new differential form[10] leads in entirely new directions. The cause of the indefinite constancy of the temperature of the sun rises from the inevitable reaction of the differential law of gravitation on the law of the propagation or radiation of energy and in particular the differential law of the conduction of heat, established by Fourier. The forms of the two differential laws must be placed in opposition to each other in order, when taken together, to correspond to the principle of energy. The very considerable rôle which the mass of bodies plays as the cause of the concentration of the forces of gravitation demands a corresponding influence of the mass of bodies on the concentration of energy. To the radiation of energy called the flow of heat there corresponds a new flow of energy in the direction of gravitation. Thus the law of the conduction of heat established by Fourier is strictly applicable only to media of extremely slight density. In dense substances there must be a hitherto unrecognized concentration of energy, and this is not an hypothesis, but simply the balance of the system of laws of effects from point to point. All dense bodies should in consequence produce heat incessantly and spontaneously. All bodies are so many radiations functioning without loss, although in very different and to us generally imperceptible degrees. Far from being in contradiction to the principle of energy, this fact springs exactly from its expression in the form of the law of effect from point to point. The salts of radium, indeed, produce a similar effect of spontaneous radiation, but this is of such an exceptional intensity that it has amazed the physicists. Upon its discovery doubts were conceived of the validity of the principle of energy, but it is only the integral form of the principle which gives place to these doubts, while the differential form, or the law of effect from point to point, is thus all the more firmly established. The increase of temperature in the deep strata of the earth is explained by this effect of spontaneous radiation without the intervention of the hypothesis of deposits of radium. Moreover, there is produced toward the sun an enormous concentration of the new radiation of energy arising from the field of gravitation, which compensates for the loss of energy which the sun undergoes and assures the permanent constancy of its mean temperature. Consequently the sun yields no energy at all to the wide circle of cosmic space; that which it radiates into cosmic space is recovered in the form of this flow of energy from the field of gravitation. The senseless waste of the sun's energy, of which the theory of effects at a distance seems to prove the existence, is shown by the theory of effect from point to point to have no place in nature. A cooling off of the sun will not bring the development of our civilization to a stop, after which, through the deterioration of the climate, it will disappear and the last men will live like Eskimos on the entirely glaciated earth. The radiation from the sun being stable, the intellectual and physical evolution of humanity will be able for an immeasurable time to mount to heights surpassing, perhaps, anything the imagination is capable of conceiving.

Thus, as a result of the development of the differential theories, a new and unsought contribution to cosmology of high and moral also essential value has been obtained.

[7] G. Jaumann, A complete system of physical and chemical differential laws, Sitzungsber. K. Akad. Wiss. Wien, Math.-Naturwiss. Kl., vol. 120, pt. 2a, 1911, pp. 385-530.

[8] G. Jaumann, The theory of gravitation, Sitzungsber. K. Akad. Wiss. Wien, Math.-Naturwiss. Kl., vol. 121, pt. 2a, 1912, pp. 95-182.

[9] The majority of physicists still subscribe to the emission theory of cathode rays (the corpuscular or emissional theory) and there is a tendency, under the leadership of Einstein and Planck, toward giving up finally the essential features of the classical theory and going back to a sort of emission theory of light.

Regarding the undulation theory of cathode rays and the phenomenalistic undulation theory of light in dispersion media, see G. Jaumann, The electromagnetic theory (Sitzungsber. K. Akad. Wiss. Wien, Math.-Naturwiss. Kl., vol. 117, pt. 2a, 1908, pp. 379-543), which paper was rejected by the editors of the Annalen der Physik in 1908 and in 1911 was honored by a prize by the Imperial Academy of Sciences in Vienna. See also E. Lohr, The boundary conditions in G. Jaumann's electromagnetic theory (Sitzungsber. K. Akad. Wiss. Wien, Math.-Naturwiss. Kl., vol. 120, pt. 2a, 1911, pp. 1503-1567, and vol. 121, 1912, pp. 633-678.

[10] G. Jaumann, Sitzungsber. K. Akad. Wiss., Wien. Math.-Naturwiss. Kl., vol. 117, pt. 2a, p. 388 et seq.; vol. 120, p. 398 and p. 505; vol. 121, p. 169.

The Conditions of Industrial Accidents*

THE enactment of laws in various States on workmen's compensation for injuries has aroused increased interest in the statistics and physical and psychic conditions of industrial accidents. The total number of these accidents is almost appalling. The lowest estimate places the fatal accidents to adult workers in the United States at 35,000 a year, with an additional 1,250,000 non-fatal accidents. The Massachusetts Industrial Accident Board, on the other hand, placed the number of workers killed by accident yearly at 75,000, which apparently includes not only adults, but also workers of all ages, while the number of injured of the same classes was placed by this Massachusetts authority at 3,000,000 or over. An earthquake in a foreign country that kills half this number of persons and maims one fiftieth of those injured in our United States industries is spoken of as catastrophic.

Among the interesting elements of these accident statistics is the fact that a greater proportion of accidents occurs on Monday than on any other day of the week. Accidents are said to be due often to fatigue, as, after the day of rest on Sunday, workmen should be less fatigued than on other days, some other factor must be sought to explain this feature of the statistics. It has been suggested that the "blue Monday" accidents are really due to the fact that workmen take more spirituous liquor on Sunday, and thus become unnerved and more liable to accidents during the following twenty-four hours. There is, perhaps, something in this contention, though it has been disputed. In the Massachusetts Industrial Accident Board Reports, in which the official figures are given, there is scarcely more than one twentieth more accidents on Monday than on Tuesday, while Tuesday is not much above the average in the number of accidents reported for other days. Saturday, of course, shows a noteworthy reduction, because of the half holiday in some trades.

By far the larger number of accidents occur at about 10 A. M. and 3 P. M. This fact is confirmed by the reports of two State boards, Washington and Massachusetts, which have secured rather careful records. As they represent the extremes of the country, the conclusions from their statistics would seem to be incontrovertible, though the fact is not what might naturally be expected. The State of Washington Industrial Commission[1] says, "These results seem to disprove the theory that fatigue is the prominent cause of accidents, because accidents are here shown to happen at the hours when the workmen are least fatigued." On the fatigue theory it might naturally be expected that most accidents would happen after 11 A. M. and 5 P. M. The actual hour of the high point of the curve of accidents shows how important are the facts and how necessary of proof the theories.

After much discussion, the tendency to speed up employment has been incriminated, as the predisposing condition for the occurrence of accidents. This desire comes over the workman when he is not yet fatigued, but has been employed for several hours. He starts the morning's work "cold," and as he warms to his work, the danger of mischance because of haste becomes greater. Just when the speeding up reaches a climax in the morning hours, most accidents happen. The same thing is true in the afternoon. Workmen feel sluggish after their lunch, but after an hour of work warm up again, and by about 3 o'clock they are doing their most rapid work, and are at the same time more subject to accident.

With regard to accidents among children, however, there is no hour of maximum. Accidents occur at all times, and they are comparatively much more frequent among children than adults. The United States Bureau of Labor reported that "there is clear evidence of great liability to accident on the part of children. Though employed in the less hazardous work, their rates steadily exceed those of the older co-workers, even when in that group are included the occupations of relatively high liability." This was said with regard to the Southern cotton mills, but the same thing is true of practically all industries in which children are employed.

The results of these accidents come to the physician. We are devoting much time to the prevention of disease, and we should be ready to give attention also to the prevention of injury. Virchow used to say that the ideal function of the physician, besides that of reliever of human ills, is to be the attorney of the poor for the prevention and relief of social ailments, and, above all, the prophylaxis of their physical consequences, whether in lowered health or in maiming injuries.

*From the *Journal* of the American Medical Association.

[1] Report of State of Washington Industrial Commission for 1912, p. 178.

Gardens of the Zoological Society of London

Its History, Organization, and Its Valuable Collections

By R. W. Shufeldt

As is the case with all the achievements of man, museums, zoological gardens and aquariums have, each and all, had their beginnings. Some of these latter have been of extremely modest pretensions, while in the case of others the starting has been upon a far broader basis, and the enterprise given an initial impulse through the influence of powerful patronage and munificent financial support, which, in any particular instance, has at once placed the institution in the foremost rank with others of its class. In the present article it is not my intention to have anything to say in regard to any museum or aquarium—these subjects will be taken up later on; but I do propose to point out some of the advantages of a first class zoological garden, and for this purpose I have selected the Zoological Gardens of London as my example.

Let me say at the outstart that these Gardens belong to the Zoological Society of London—an organization of world-wide reputation, which was incorporated by Royal Charter as long ago as the year 1829, having for its main object the advancement of zoological science—a mission which it has most efficiently performed for a period extending over three quarters of a century. Personally, I have always taken an active interest in the welfare of this Society; and as I have been one of its corresponding members for nearly 30 years, I am more or less familiar with its history, the history of its gardens, and with the enormous influence the two combined have had in promoting the best interests of the science of zoology throughout the civilized world. While it did not receive its charter until 1829, these gardens were first opened to the public a year before that time, or on the 27th of April, 1828. This statement, however, will by no means enlighten the reader upon the highly interesting question of the origin of these gardens—a point I desire to refer to before passing to matters of a more recent nature.

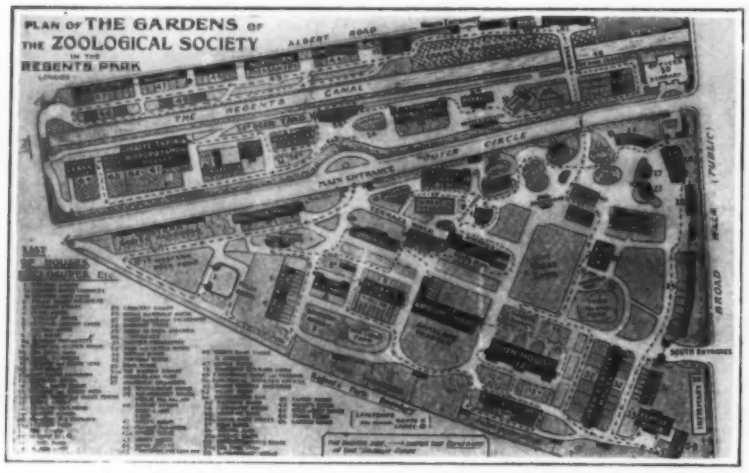
In order to discover how zoological gardens first came into being—if one be so fortunate as to ultimately obtain such information—it behooves the searcher to scan the historical records having reference to them, and it will soon be discovered that the most valuable of these date from the time of remotest antiquity. Such tracing quickly carries one into the musty tomes of the fabulous ages, where traditional history soon becomes obscure and the thread of investigation is lost. In those archaic times collections of living animals were known as menageries, and in the main they consisted of collections of large mammals (and sometimes birds) obtained by the "monster-queller" who, for that purpose, accompanied the armies of invasion in the days of ancient Greece and Rome. These nations, in many respects, were barbarians in those days, and most of us know of the brutal and fiendish uses to which these captive lions and bears, tigers and leopards were put in the public arenas and in the dungeons of the cities of the conquerors.

Still, as the years passed by, these very early nations, with all their cruelty and barbarism, in time presented the evidences of the dawn of thought and observation. Individuals appeared from time to time who, in an era of increasing leisure, devoted themselves to philosophic studies of their environment, and in this was included the wild and captured animals which came within their ken. Sentimental as this movement was at first, it speedily became the foundation for more exact zoological research, and the dawn of scientific investigation set in.

Thus it stood in later Greece when the Macedonian conqueror, Alexander, led his victorious armies eastward, even to the very banks of the Indus. Never did he allow an opportunity to pass through which he might further the aims of science or add new animals to the marvelous "menagerie" he had already formed at his native capital. Aristotle, his old friend and tutor, took up the serious study of these treasures and reveled in the extensiveness of the undescribed material at his hand. In due course it bore its fruit, and the world was given one of the most original and greatest zoological works of the period: Aristotle's *History of Animals*.

A somewhat similar growth of natural science took place in Rome during the same period but along different lines; here the public menageries were replaced by the private *vivaria*, supported by individuals of leisure and affluence. The later Cæsars were then in power, during their regime, Pliny produced that very ex and marvelous production—his work on the history of animals. As we are now aware, every of its reeks with error, or is rendered worthless the flagrant introduction of the fabulous and the lous.

But we are not concerned with these writings or with the extraordinary times during which they peared; I aim but to refresh the mind of the reader respect to the origin of menageries in ancient G and the formation of the *vivaria* in early Rome. fully fifteen centuries thereafter there was no



Plan of the gardens of the Zoological Society in London.

South entrance to the Zoological Gardens.

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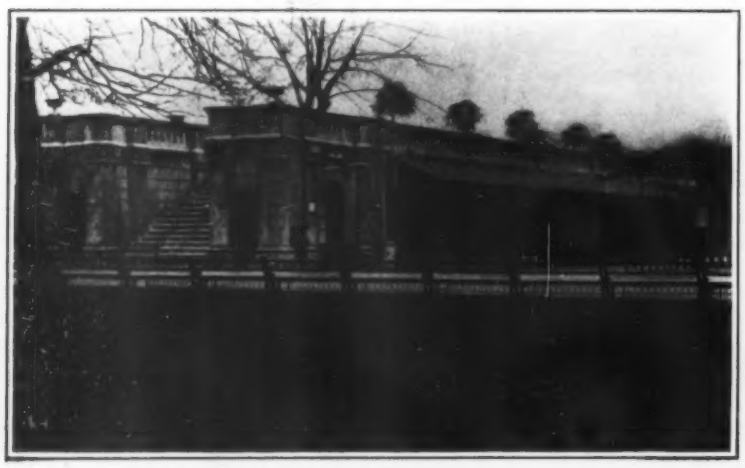
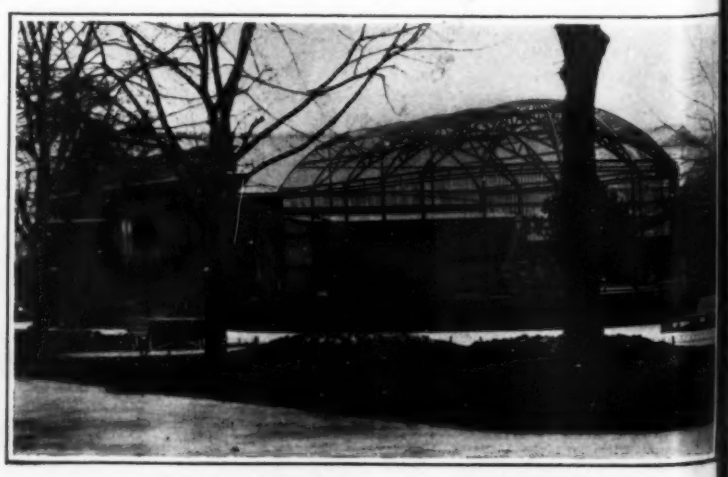
It was not until Louis the Fourteenth founded sustained a menagerie at Versailles that the interest such institutions was again revived on the Contin and writers once more appeared to take advantage what was at hand for them—that is, a large and va collection of captive animals, and such other mate as the early museums there supplied. The *Natu History* of the highly imaginative Buffon followed did, about the same time, the far more exact work Daubenton—respectively the Pliny and Aristotle those later times.

In London—very early London—was the To Menagerie, which may be said to have been the ance of the present Zoological Gardens of the Zoological ciety of London at Regent's Park. This Tower Mena erie possesses a wonderfully interesting history, and o I may say, far too extensive to be touched upon in t article. In 1828 there was an admirable collection on pu lic exhibition there consisting of a large number of ve valuable animals, some of which, later on, found th way into the present "Zoo." There were about six different forms, chiefly mammals, while there still re mained with them a number of birds and reptiles—amo the former a great horned owl and among the latter

up anywhere in Europe of a menagerie or a zoolog garden, while the entire science of animal history steeped in fable and shrouded in the rankest atmosph of ignorance.



The Fellows Pavilion and the bear den.



The lion house, Zoological Society, London.

The white pelican.

…nake, these in evidence of the fact that even at … early day, upwards of a century ago, wild forms … being obtained in America for exhibition in Lon-…

The Zoological Society as now organized consists of …ly 4,400 Fellows and, taken together, of some 300 …eign, Honorary and Corresponding members. There …lected annually a council which governs it, and King …orge, who has been a Fellow since 1894, is its patron. …e Duke of Bedford is its present president, and its …retary is Dr. P. Chalmers Mitchell, F.R.S. At stated …ervals it issues *Proceedings* and *Transactions*, the …ter being a sumptuous publication in which has ap-…ared many of the most famous zoological contributions … the English language. Reports upon the animals of …e "Zoo" appear, as a rule, in the *Proceedings*.

Among other buildings there is a fine library and …ces at Regent's Park, which is located at No. 50, … shown on the accompanying plan. I may say in …sing that all the views shown of the park and its …ildings in this article were kindly made for me by …r. F. W. Bond, F.Z.S., the official photographer to …e Society, who has a wonderful collection of photo-…aphs of animals which have been kept at the "Zoo," … secured by himself.

These London gardens occupy but a small extent of …ound in the very heart of the city. There are not over … acres in all, though the views would lead one to sup-…se that the place was considerably larger. As will be …n by the accompanying plan, the grounds have been …mirably laid out, and that with the view of making …e many inmates as comfortable and contented as pos-…le, compatible with the economical apportionment of …ace. As a property, these gardens are held from the …own, through the Office of Woods and Commissioner … Works, at a fixed annual rentage.

It is scarcely necessary to say that there is a dis-…guished staff of naturalists connected with these …rdens, and a very large body of workmen employed … perform the many duties associated with such an ex-…nsive institution. Some of England's greatest scien-…sts have, in the years gone by, been connected in one …pacity or another with the "Zoo," and the extent of …e published researches made by them is one of the …ndest monuments that has ever been erected to …logical science.

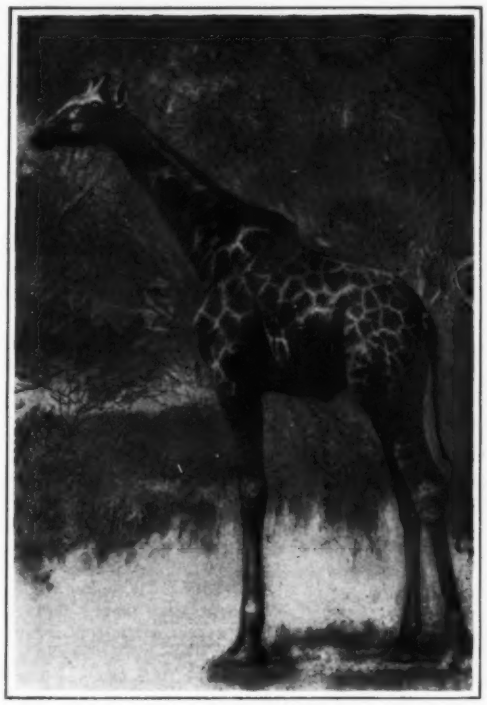
Hundreds of animals of all kinds are upon exhibition …re at all times, and the list of those which have been …t there in times past is not only enormous, but in-…des nearly all the forms known to us—that is, in so … as the vertebrates are concerned. Each year the "…eports of the Council and Auditors" are published; … to gain some idea of the grand scale upon which …ese gardens are conducted all that is necessary is to …d one of these documents of recent date. For ex-…ple, "The number of Vertebrate Animals living in …e Society's Menagerie at the end of 1912 was 3,595. …e corresponding number on the 31st of December, …11, was 3,847." All these require due care and *feeding* …wo pretty extensive items.

There is a most efficient Prosectorial Department con-…ted with these gardens, and an infirmary (No. 30, …an) where highly important investigations are made …on the causes leading to the death of the animals that die in the collection, as well as researches upon their anatomy, both normal and pathological. Mr. F. E. Beddard, F.R.S., is the present prosector, and Mr. H. G. Plimmer, F.R.S., the society's pathologist. An enormous quantity of excellent work has been done here, which for years past has been published in the society's *Proceedings*.

The admittance to these gardens is quite special, as a charge is made for admission of one shilling for adults and a sixpence for children. On Mondays, however, and on certain advertised days, it is sixpence for everybody, and on Sundays the gardens are closed except to Fellows and their friends who gain admission with special tickets.

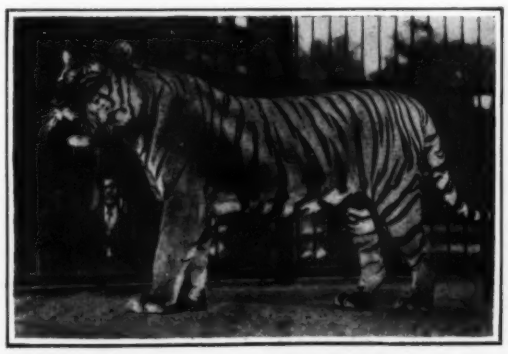
The society publishes an official guide-book, which is not only beautifully illustrated with pictures of a large number of the animals—half-tones from photographs—but it prints a great quantity of information about them as to their habitats, habits in nature, breeding, and much else besides. Some of these accounts are more extensive than one finds in works on natural history and certainly more trustworthy.

Under the giraffe-house for instance (No. 62), we read in this guide that "The first living giraffe which is known to have reached England was sent to his Majesty King George IV. in the year 1827. It lived two years and two months. In the summer of 1836, four giraffes from Kordofan reached the gardens safely. These succeeded in the most remarkable manner, and no less than seventeen individuals were bred in the Society's gardens from these animals or their descendants. In 1881 the last survivor of this stock died; but the Society was able to purchase other examples and to exhibit them until the last died in 1892. At that time, and for some years afterwards, the Soudan was practically closed because



The Southern giraffe.

of the rise of Mahdism, and the next arrival was a fine young female imported from South-east Africa, which, however, died in 1907. A pair of giraffes from the Egyptian Soudan was presented to the society by Col. Mahon, the governor of Kordofan, in 1902, and from these was born in September, 1907, a young female, which has been successfully reared. The coloring of giraffes from different localities varies very much, and some naturalists believe that a number of species, and perhaps two genera, should be recognized." All the principal mammals and birds in this guide of over 100 pages receive such notices as the foregoing, so that the body of information thus presented is both valuable and instructive.



Prince, the Indian tiger.

The Beisa oryx.

As I know from personal experience, the Society is very glad to receive at any time living animals for its menagerie, and these are invariably fully acknowledged in its annual report in the year in which donations of the kind come to hand. I usually send such animals by express in properly constructed cages, and I have thus succeeded in transporting different species of turtles, "horned toads," an Arizona squirrel, and so on. The list of such donations during a year usually number several hundred from all sources. Occasionally, these are of unusual extent and correspondingly valuable, as for example, when the King last year presented the gardens with the Nepal collection, consisting of 48 large and rare mammals, and 17 birds, while the Duke of Bedford and the government of the federated Malay states presented, during the same year, many animals of the greatest value.

The installations of such collections as these at the gardens form occasions in which the royal family not only take part but greatly excite the interest of the public afterwards. For instance, in the case of the King's Nepal donation, it is reported that "The collection, on board the British India Company's S.S. 'Afghanistan,' reached the Royal Albert Docks on May 20th and arrived at the gardens before 8 P. M. The animals were at once installed, as all arrangements had been made for them, and they were on view to visitors on May 21st. The King and Queen and Princess Mary visited the gardens on the afternoon of May 31st to inspect the animals. By the King's wish the visit was strictly private, and no special preparations were made."

As will be seen from Mr. Bond's interesting photographs, some of the views in the London gardens are very attractive, and along the canal and elsewhere one can hardly realize that the places are in the very heart of the largest metropolis in Europe.

The entire management of these gardens is carried out along strictly scientific lines and under a plan of management which appeals to anyone who appreciates extreme tidiness, system, and proper presentation of the animals he resorts there to study; and such a one cannot fail to be encouraged by the knowledge that, behind it all, science is constantly utilizing the material, through published papers and reports, to the advancement of civilization and to the national credit of the country sustaining the institution.

Efficiency of Coal and Electric Heaters

CONCERNING the importance of efficiency of electric and fire radiators, but little general information has been given out. In some recent experiments it is stated that an electric lamp radiator gave out 548 watts, against 1,000 put in, or an efficiency of 52 per cent. On the other hand, a fire radiator produced 727 watts out of 1,570 put in, giving an efficiency of 46 per cent. There are, however, other questions than those of comparative efficiency to be considered, as, for example, first cost and cost of maintenance, which is undoubtedly greater in the electric outfit. The care necessary for operation and the space occupied are also often important.

A New Era in the Science of Nutrition

How Two Masters in the Art of Experimentation Are Bringing This About

By R. L. Kahn, M.S.

About four years ago, Dr. Thomas B. Osborne and Prof. Lafayette B. Mendel, began a series of feeding experiments at New Haven, which have had the high distinction of being epoch making from the very beginning. They have been epoch making because chemical analysis, physical measurements and mathematical precision underlay their procedure. These experiments are still being continued and the scientific world waits and wonders what these investigators will unearth next.

It is nearly 30 years since Dr. Thomas B. Osborne was appointed Research Chemist at the Connecticut Agricultural Experiment Station. His many investigations in the chemistry of foods during all these years, have given him a name equaled by few in the entire world of science.

Prof. Lafayette B. Mendel, although comparatively young, has occupied the Professor's Chair in Physiological Chemistry at Yale University for over 15 years, during which time he has gained enviable fame as a chemist of animal life. And to-day his laboratory is the Mecca for those students whose aim is to solve, by chemical means, some of the mysteries of animal life.

These investigators, with the assistance of Miss Edna K. Ferry, Dr. Alfred J. Wakeman and a host of chemists of the Connecticut Agricultural Station, made up a gigantic scientific-research combination, with the modest aim to clear new ground and extend the road of the unexplored territory in the science of nutrition.

MANY-SIDED EXPERIMENTS.

The most important period in the life of an animal is undoubtedly the time of its growth, when its bodily foundation is being laid and the body structure built. These investigators showed us that Nature will not build an animal body if the supply of proper building material be withheld from the animal—if it be improperly fed. The young animal under these conditions need not be underfed; on the contrary, it may consume enormous quantities of improper or inadequate food; nevertheless, it will not become larger and gain in weight—it will not grow—as young animals should and ordinarily do.

The effect of nutrition on growth is, however, only a small measure of their far extended investigations. The rôle bacteria play in digestion, the importance of the inorganic constitutents in our diet, the relative nutritive value of different fats, such as butter and lard, and a number of other problems of practical concern to man, have been investigated by these workers. And when we consider the far reaching importance of these experiments it becomes clear to us why the scientific world has taken such an active interest in them. Efficient and economic feeding is not only of importance to man in his personal pursuit of health and happiness, but to the cattle raiser as well. Science is the greatest waste eliminator we have, and ultimately it will prove to be *the* important factor in reducing the high cost of living.

FORMER VIEWS.

It is needless to say that experiments of this nature could not have been undertaken had we still believed that "the food we ate was first converted by the liver into natural spirits, which the blood and inspired air changed into vital spirits and which, on reaching the brain, became animal spirits." Neither would these investigations have been possible had we still thought that the meat (protein) we eat, became body flesh with very little transformation.

It was this latter view which led Justus von Liebig, the great pioneer in physiological chemistry, to suggest that the best food for one who works with his muscles is some other animal's muscle, such as beef. This theory could never make clear how the ox builds up its beef on a purely vegetable diet. We know now, beyond the slightest shred of doubt, that the energy required for muscular work is furnished largely by the carbohydrates (starchy foods) and fats.

Unfortunately the Liebig view is still popularly accepted. Again and again friends advise us to eat meat for strength, forgetting that our domesticated animals which display the most strength, such as the horse and bull, are herbiverous animals and live on a vegetable diet exclusively. This is not an appeal for vegetarianism. Man should eat meat, but let him eat it moderately and not entertain the idea that it supplies him with energy for muscular work.

The erroneous corpuscular theory of light, formulated by Sir Isaac Newton, which kept the world in darkness for several centuries, until the wave theory of light finally conquered, is a similar example in the field of science of a great man's error and its influence.

It is evident that, just as the helpful suggestions of the great exert a goodly influence, in the same way, and to the same degree, do their erroneous views exert their harmful effect.

THE PROTEIN MOLECULE, A HUGE STRUCTURE.

The greatest interest in the study of nutrition attaches itself to the protein molecule; the nitrogenous molecule which goes to build up the various tissues of the animal body. The carbohydrates and fats are our coal foods; they furnish us with the same amount of heat and work energy which they would furnish an inanimate heat engine if burnt in it. But how the protein of a grain of wheat can be transformed into a nerve fiber, a drop of blood or a muscle cell, appeared until recently quite inexplicable. It was known for a long time that the grain of wheat was first broken down in the digestive system, after which the body would utilize the broken down products, to suit its own needs. Further than this, however, nothing was known.

Thanks to the recent laboratory investigations, we now know the chemical nature of the protein molecule better than we ever did before, and we can follow up its life cycle in the animal body with much precision.

The protein molecule, although physically not big enough to be seen with the highest magnification under the microscope, is, nevertheless, chemically a very huge structure. Should we break it up it will yield an enormous number of other molecules. These new molecules the German scientists have christened with an unusually appropriate name. They call them Bausteine (building stones), they being the building stones which go to make up the protein molecule. These building stones are definite chemical substances known as animo acids.

DIFFERENT BUILDINGS WITH SIMILAR BUILDING STONES.

When a protein molecule is allowed to come in contact with acids or digestive fluids, the building stones or animo acids are liberated. These building stones can now serve as the material with which new protein structures, such as liver, brain and muscle protein may be built. This in fact, is what takes place during digestion. The digestive fluids liberate the building stones of the proteins which we eat. These building stones enter the circulation and are distributed to the different tissues of the body, where they serve as the building material with which the body builds new tissues to suit its own needs.

We can now understand how the lion in the jungle, the cow in the stall or the bird in the nest, can build up tissues which are so similar on foods so entirely different. The mystery was solved when the laboratory student subjected a large variety of foods to chemical analysis, and found to his great surprise that the building stones of the various proteins found in these foods were essentially the same.

Just as we have in any city a large variety of structures built with similar materials, we have in nature a large variety of proteins built with similar animo acids. Some structures in our city, embodying more building material, are larger than others; others, again, containing different proportions of certain building stones may vary in form or style. Similarly, some of our proteins lack animo acids, like gliadin of wheat and zein of maize, and are therefore smaller—or to use a laboratory phraseology—are incomplete proteins. Other proteins again, are believed to contain different proportions of certain building stones. Thus, for instance, albumin of egg and globulin of meat are two complete proteins; i. e., as far as is known, they do not lack any animo acids, still they possess different chemical properties. It is extremely probable, therefore, that these two proteins contain varying proportions of the same building stones.

The blood of the lion, cow, bird or any other animal, knows not whether the source of the building stones which come to it be a grain of wheat or a bit of flesh. This is not its business. It is the business of the animal to obtain food, that of the digestive system to convert this food into energy-yielding and tissue-building material, and it is the blood's duty to receive the daily supply of this new material, particularly the tissue-building material, or animo acids, and distribute it to liver, muscles and other organs of the animal body where it may be utilized to rebuild the cells which are being broken down in the daily wear and tear.

A VISIT TO THE LABORATORY.

Let us now spend a few minutes in the laboratory where the experiments with which we are most concerned are being carried on. We are all sufficiently advanced in the science of nutrition to understand fully the work of our investigators.

Here we are in a large and dignified brick building on Huntington Street, New Haven. It is the newest building of the Connecticut Agricultural Experiment Station. We will enter to the right the spacious room on the main floor and watch the chemists at work. Practically all are busily engaged isolating proteins from various food stuffs. We see one adding an acid solution carefully to a 10-gallon jar containing milk. We can see the floculent precipitate of casein being formed as he adds the acid. He is separating the casein from the milk. Another is isolating edestin from hempseed. A third is re-purifying the glutenin he obtained from wheat, and so down the line. Every one seems to realize the importance of his work, for these isolated proteins are to be used in the feeding experiments of Osborne and Mendel.

In another room we see several hundred cages, each about the size of an ordinary bird cage. In each of these cages one or more white rats are slumbering. These animals sleep during the day and are active at night.

The white rat serves as the experimental animal because of the relative ease with which it can be looked after, and also because the life cycle of this animal and its relation to man has in recent years been carefully studied by Prof. Donaldson at the Wistar Institute.

The duration of life of the white rat is three years. For 20 days after birth it will depend upon the mother for sustenance. It is sexually mature at the age of 60 days, and its entire growth period is completed when it is 280 days old. The first year of the rat's life corresponds to the first 30 years of human life, and, according to Prof. Donaldson, the 3-year-old rat is very old—comparable to the 90-year-old man.

MAINTENANCE AND GROWTH.

To begin with, the diet of these animals consisted of starch, lard and inorganic salts to which was added some isolated protein. Soon our investigators established the fact that there is a difference between the requirements of a mature animal and that of a growing animal. The adult animal needs protein material with which to repair the daily wear and tear of its body; the growing animal needs protein material with which to build up its body. They found again and again that diets which were sufficient to maintain an adult animal in good health were not sufficient for a young animal to grow on.

This, in reality, is what we would expect. You cannot often build a machine with the materials with which you can repair it; and the food which can adequately repair the animal machine may not be sufficient to enable the animal to grow and build up its body. Nature set down more rigid food requirements for the young animals than for the mature ones, to make sure that the bodily foundation which the former build during their period of growth be of solid and strong material so that it will withstand weathering later in life.

Growth is, indeed, a very mysterious phenomenon in the life of an animal. The growth-impulse, or "*Wachstumtreib*" as the German physiologists call it, is inherent in all animals. It appears to be a function of the young animal cell. Nutrition, no matter how rich, can neither hasten nor prolong growth; if inadequate, however, it will interefere with the growth of an animal.

UNDERFEEDING AND IMPROPER FEEDING.

There appears, also, to be an important difference between underfeeding and improper feeding. If you underfeed an animal, that is, if what you give it is nourishing food but of insufficient quantity, you will not interfere with its ability to grow. Its growth, however, will be at the expense of its own tissues. The bones will enlarge, but the muscles and other tissues, not receiving sufficient nourishment, will waste away.

Should an animal be improperly fed, as is the case when you feed it with an isolated protein which lacks building stones, growth itself will be interfered with. Under these conditions, no matter how large the quantity of food the animal may consume, it will not grow.

Take for instance Rat 240. Its diet consisted of starch, lard, inorganic salts and gliadin, one of the proteins of wheat which is known to lack several building stones. At the age of 140 days it weighed only 55 grams, when it should have weighed about 150 grams. Now this animal did not suffer from underfeeding; it ate well and its energy requirements were fully supplied, nevertheless, it was unable to grow. It is fair to assume, therefore, that the lack of some building stones in its food prevented this animal from building up its body.

THE FRANCHISE TO MANUFACTURE BUILDING STONES.

It has been known for a long time that an animal can not live without certain specific food stuffs. An animal needs to have some carbohydrates with which to supply its body with heat and work-energy. It needs calcium with which to build its skeleton, and other inorganic salts to maintain its body fluids in proper chemical equilibrium. And, finally, it needs protein, or more

specifically, building stones, with which to build the animal machine.

Withold protein, carbohydrates or inorganic salts from the diet of an animal and the animal cannot live. However, feed an animal with a protein which lacks several building stones and it will live, but will not be able to grow.

This is very remarkable. Nature starts out an animal in its struggle for existence with the most abundant equipments for life. All its organs contain far more material than it actually needs. More than half of its liver and pancreas can be removed with impunity. Remove a lung or a kidney, or let an animal lose more than half of its blood, and still the animal will have its health. Nature provided the animal with every conceivable means to continue its life in the midst of adversities. However, the franchise to manufacture building stones nature granted almost exclusively to the plant kingdom. And if you withhold building stones from an animal's diet the workers of the animal machine will lay down their tools. Work will stop. The animal structure will not be built.

Supply plants with the raw chemical elements, such as carbon, hydrogen, nitrogen and so on, and sunlight, and the most complex structures will be built by them. Animals can not do this. The digestive systems of animals can only break down the structures built up by plants, liberate the building stones and utilize them to build up the animal body.

WHEN NATURE OVERRULES HER OWN LAWS.

We always think of Nature as doing her work in an orderly and well-regulated manner. It is difficult to conceive of Mother Nature hurrying about her work. In guiding the building of an animal body nothing can lead Nature off her path, providing, of course, that the animal receive the proper building material. A rich diet will not bribe her; the animal may store up some fat, but its growth it cannot hasten.

If, however, an animal which is stunted for a given time, due to improper food, begins to receive a diet which is adequate, it will immediately begin to gain in weight and grow by leaps and bounds. Nature then will overrule her own laws of growth in order to help the animal gain what it had lost.

Rat 208, for instance, received a diet similar to that received by Rat 240, gliadin of wheat serving as the only protein. The animal was stunted for 40 days; then a part of the gliadin was replaced by casein of milk. This new protein supplied the building stones which gliadin lacked; the animal began to grow with unusual rapidity, and quickly gained what it had lost during the period it was stunted.

It is evident that Nature provided the cells of young animals with a far greater growing capacity than that which they normally make use of during their period of growth. Here we have still another of Nature's provisions for the well being of animals.

THE INORGANIC SALTS.

No phase in the diet of an animal has been overlooked as much as the rôle of the inorganic salts in it. They neither supply us with heat and work-energy (with the exception of calcium which goes to build bone) nor serve as material with which the body builds its tissues. Nevertheless, life is impossible without these salts. To remove the inorganic salts from a diet is more fatal to an animal than starving it. An animal which is able to live 60 days without food will not live half as long if its food is free from inorganic salts.

The inorganic salts seem to regulate the concentration of the fluids of the body. We know from experience to what extent our intestines become flushed when taking a saline cathartic. Fluids from all parts of the body rush to the intestine in order to dilute the concentrated salts and bring it in equilibrium with the other fluids of the body.

The inorganic salts are as important to the life of an animal as cement to the brick structure. Remove the cement and the structure can not stand. Remove the inorganic salts from our diet and life is impossible.

Mixed foods ordinarily contain sufficient inorganic salts to supply the needs of the animal body. The adding of table salt to our diets is, in most cases, the result of habit and not, as is the opinion of some, because the body actually requires the additional salt.

The white rats, being supplied with chemically isolated food materials, had to receive definite quantities of inorganic salts in their diets. After overcoming a number of difficulties our investigators furnished the inorganic salt requirements to these animals in a very novel fashion. They removed, by chemical processes the proteins carbohydrates and fats of milk, and left in it the inorganic salts. This fluid contained inorganic salts in the proportion in which Nature provided, and by adding it to the diet of these animals, it served the purpose excellently.

THE RÔLE OF BACTERIA IN NUTRITION.

The fear of germs has been so exaggerated in recent years that it is causing far more harm than the very bacteria which are most pathogenic. Indeed, the lowered resistance to disease which fear is sure to bring on will often make one susceptible to the bacterial diseases which he fears most. Of the countless bacteria which fill the air, water and soil, those that are known to bring on disease can be counted on our fingers, while the rest are busily engaged in enriching our soil, purifying our water, flavoring our foods and, in many other helpful fields of pursuit, being possessed with the single aim of making animal life possible.

We have known for some time that bacteria play an important part in the processes of digestion without, however, knowing definitely what this part is. Osborne and Mendel have shown specifically, in the course of their experiments, that bacteria exert a beneficial influence in the alimentary tract of animals.

The diet which they gave the rats, being chemically pure, was almost free from bacteria, and the animals under these conditions would often show signs of ill health. They thereupon decided to supply their animals with the proper bacterial flora. Their scheme was to add to the diet of their animals small quantities of excreta obtained from rats which were fed on regular mixed diets. Their rats thus obtaining intestinal bacteria of normal animals, showed marked improvement in practically every case.

To remove the possibility that there were other ingredients in the excreta, besides bacteria which brought about the beneficial effects, they killed the bacteria by sterilizing this material and fed it to the animals as they did before. The result was that the helpful effects were not in evidence.

That bacteris are helpful factors in digestion ought to be impressed very strongly, if for no other reason than to help allay the prevailing fear of these little bodies. The pathogenic germs can do us no harm unless they are given an opportunity to grow in our tissues, and this we virtually permit them to do whenever we lower our resistance by over-worry, fear, etc. In health, however, our bodies are sufficiently equipped to overcome the disease germs.

THE FATS.

We have spoken before of the importance of proteins, carbohydrates and inorganic salts in the foods of animals, to the extent that the removal of any of these from an animal's diet would cause the death of that animal. Whether or not fat is essential to the life of an animal has also been studied by these investigators.

They fed a number of animals with diets which were almost free from fats, and found that such diets did not interfere with the health of the animals. It would appear, therefore, that animals can grow and maintain good health for a time on a diet which is nearly free from fat.

This, it is readily seen, is only of scientific importance. In actual life it would not be advisable to eliminate fats from our diets on account of their relative cheapness and high heat value.

Osborne and Mendel have very recently carried out a series of experiments which have a more practical bearing. They tested the relative nutritive value of butter and lard. Butter, according to their experiments, is far more nourishing than lard. Animals which appeared weak and ill when getting lard in their diet showed marked improvement when butter was substituted.

At the present time these scientists are concerned in the study of the relative nutritive value of the various vegetable fats, such as olive oil, linseed oil, etc.

The experiments of Osborne and Mendel are known and discussed in every biological laboratory in this country and abroad. They have caused old theories to fall, and new theories to form. The science of nutrition is undergoing a period of reformation, and we feel not a little proud that two American scientists are among its reformers.

Recent Developments in X-Ray Tubes*

PROF. W. C. RÖNTGEN of Wurzburg, Bavaria, suspected that when a current of electricity passed through a glass tube containing a gas at very low pressure, invisible light waves were given off. The idea occurred to him that such rays might affect a flourescent screen in much the same manner as did ultra-violet rays. In order to cut out the visible light from his vacuum tube he wrapped it in heavy black paper. Upon operating the tube to make certain that the covering was completely light-tight, he noticed to his surprise that the fluorescent screen which he had left on the table three or four meters away glowed brightly.

Röntgen investigated the properties of the X-rays with characteristic German thoroughness. By 1897 he had amassed such a volume of information about X-rays that nearly every essential piece of research on their properties up to 1908 can be found in its more elementary form in his three original memoirs.

Röntgen's original tube of 1895 was, judged by modern standards, a pretty crude affair. The cathode was flat and emitted a diffused bundle of cathode rays which, upon hitting the glass at the far end of the tube, produced X-rays. In 1896 Campbell-Swinton added a platinum target upon which the cathode stream hit. This increased the penetrating ability of the rays obtained. In the same year Jackson made the cathode concave so as to focus the cathode stream upon a small area of the target. By giving more nearly a point source of X-rays this increased the clearness of radiographs for diagnostic purposes. The X-ray tube was soon changed in form, but not in principle. A device was added by which the pressure inside the tube could be increased at will, and various means were tried for removing heat from the focal spot of the target.

Meanwhile in 1912, Dr. Coolidge discovered the process of making ductile tungsten such as is used in the filaments of mazda lamps. Shortly after this discovery he became interested in perfecting a wrought tungsten target for X-ray tubes. During this work it became necessary to operate the tubes up to the limit of their capacity in order to find out how much abuse the tungsten targets would stand. During the course of this work he found that the ordinary aluminium cathode could be melted if sufficiently high currents were sent through the tube. He tried to remedy this by substituting a cathode made of tungsten whose melting point is very high. But such tubes were found to be very unstable. When current was sent through such a tube, the vacuum increased rapidly until finally no current would pass through the tube until gas had been liberated from the vacuum regulator. From a practical standpoint such a tube was hopelessly unsatisfactory. Finally it was found that if the process of operating the tube and immediately reducing the vacuum were repeated rapidly enough, the cathode became hot enough to glow, and that after this the tube would operate for several minutes at a time without it being necessary to let in fresh gas from the regulator. This suggested the idea of a cathode heated by some external means.

Richardson, and others in 1902, had shown that electrons could be obtained by merely heating the cathode, but had not been able to obtain constant results. Dr. Langmuir of the Research Laboratory of the General Electric Company, had shown that the rate of emission of electrons from a hot tungsten cathode in a very high vacuum depended only upon the temperature.

If we heat a tungsten filament, electrons are given off and soon a condition of saturation occurs around the filament. If the filament is made the cathode of a low-potential circuit, a small current passes. If the voltage is increased, a larger current passes. Finally a voltage is reached which sweeps away every electron as fast as it emerges from the hot tungsten. For all voltages above this, the current is constant, and is independent of the voltage. Thus we have a resistance as far removed from the ordinary Ohm's law resistance as possible. This is not because the conduction is carried on in any different way, but because the number of available electrons is limited. (The reason that Ohm's law holds in conduction through wires is that the supply of available electrons in the wire is practically unlimited.)

As a source of electrons in his tube, Dr. Coolidge made use of a small spiral of tungsten wire heated white hot from a storage battery in exactly the same way in which electric automobile lights are operated. This spiral is the cathode and a block of gas-free tungsten is the anode. The rate at which electrons are given off from the spiral depends upon its temperature, which is under the immediate control of the person operating the tube. The voltage across the tube is also controllable at will. As the voltage employed in ordinary X-ray work is much greater than is necessary to snatch all the electrons across from cathode to anode as fast as they are evaporated from the filament, even at the highest currents now in use in X-ray work, the voltage and current passing through the Coolidge tube are totally independent. Both may be adjusted to any desired value with any degree of precision desired, and at any such adjustment the X-ray performance of the tube can be duplicated time after time.

* Abstract of an address by Dr. W. D. Coolidge before the Edison Club, at Schenectady, and reported in the *General Electric Review*.

A Novel Engineering Expedient

OUT in Honolulu it became necessary recently to lower a large and heavy steel tank into a deep pit where there was very little space beyond the dimensions of the tank, so that the workmen had no room for ordinary blocking of the size required. The difficulty was met by building up a blocking of ice, and subsequently melting it out by steam.

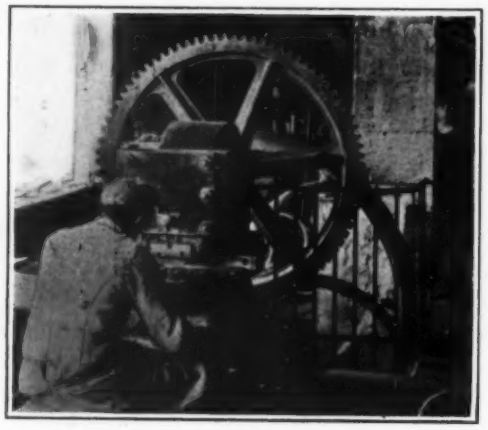
Stamping makers marks on blades.

Tempering knife blades.

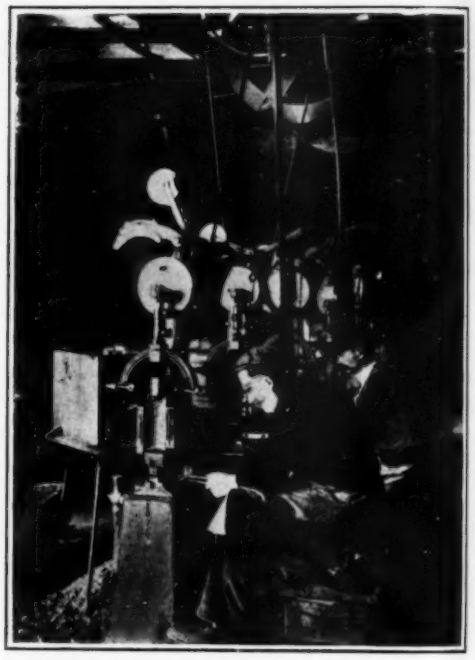
Turning handles.

Making the ferrules.

Stamping ferrules by a drop press.



Forming blades on a punch press.



Drawing blades under power hammers.

The Cutlery Works of Thiers

Manufactures of the Old French Town Where Knives Have Been Made for Centuries

By Jacques Boyer

With its cutlery shops scattered along the water's brink on the right bank of the turbulent Durolles, Thiers is one of the most picturesque villages of France. Built one after the other at the bottom of the valley, these curious workshops, known throughout the district as "wheels," contain each some 6 to 12 grindstones, and in the course of a year thousands of knife-blades are sharpened in them. The workman, it should be said, labors as he pleases in these shops, as he is merely a tenant of the place he occupies in return for a rent of 80 to 100 francs a year to the owner of the "wheel." Thus, he preserves his liberty and comes when he sees fit to perform his severe task.

The operation of knife-grinding (in a primitive and painful but original fashion) is still carried out at Thiers. The grindstones revolve on a horizontal axle set a little above the river and the lower part of the stone dips into the water, which thus acts at the same time as a lubricator and cooler. The Durolle furnishes all the motive power for the entire workshops in which grinders are seen lying on their stomachs on planks. The plank, slightly inclined toward the workman, rests on a scaffolding, and its hardness is softened by a cushion or sheepskin. Keeping the head and shoulders up in the air, each man holds in his hands below the plank the piece of steel cut out by a punch from which he is to make a knife-blade by pressing it against the circumference of the grindstone. When it is necessary for the grinder to exercise considerable pressure, either to make the point or to thin a part where the metal is too thick, he raises himself slightly and presses the blade against the grindstone with all the weight of his body. On account, however, of the humidity prevalent in the "wheels," the poor fellow stretched at full length is easily benumbed and ends by being very rheumatic.

To avoid these ailments, therefore, as much as possible and to keep themselves from getting cold, the grinders use little dogs as "furnaces."

When ready to begin work each one of them whistles. Immediately a faithful little dog, trained to this task, comes to roll himself up on the crossed legs of the grinder. The intelligent animal covers its master's legs as much as possible, and at times stretches itself upon the grinder's back; in this way it communicates a gentle heat to him without which the lack of movement would cause the master to become chilled in a short time. The poor animals seldom live to grow old. After having filled for several years the office of a living "footstove" they become crippled, are killed to save them from useless suffering, and are replaced by another spaniel or nameless mongrel.

As early as the thirteenth century the "*coste liers*" (old French for cutlers) were carrying on their work in the old Auvergnat town of Thiers, but the first authentic documents discovered by the archeologist Gustave Saint-Joanny only go back to the end of the fifteenth century. These papers are, first, a pardon granted in the month of October, 1460, by King Charles VII to a cutler of Thiers, Jehan d'Urson, who had compromised himself by making the molds used by a Parisian goldsmith named Faurel to turn out base money at the chateau of Saint-Cirques near Issoire. Then, a fragment of the land-book of the baronry of Thiers, dated 1474, shows that a fourth of the population was at that time engaged in the cutlery trade. The industrial activity of Thiers began about this epoch, as did also that of Sheffield, and the town developed into an important cutlery center; this importance continued until the eighteenth century, when the industry began to decline. However, the knife popularly called *eustache* was still manufactured in Auvergne and excited the admiration of Fox at the exposition of 1802. The

Museum of the Louvre has a genuine example of this knife with a blade closing without a spring; on the one side of its wooden handle is the word "veritable" (genuine) and on the other "Eustache Dubois," name of its maker in Thiers. The expression *eustache du bois* (wooden eustache), generally used in France to designate this kind of knife, is therefore incorrect.

During the nineteenth century the manufacture of knives steadily improved in France. From 1843 in particular the cutlers of Châtellerault began to use machinery for the mechanical manufacture of the handles; then came forging and filing machinery, which improvements were adopted long afterwards by the factories at Nogent and Thiers.

At the present day two classes of knives are made—knives that do not close, as table-knives, and spring-knives, as pocket-knives.

This much being clear, let us take up the processes in the manufacture of knives which do not close, and begin with "the blade of the eustache," the blade which it is necessary in succession to forge, harden, grind in order to obtain the cutting edge, and finally to polish.

Steel rods of good quality having been selected, they are divided into equal lengths, which are drawn out at one end to form the blade and at the other to form the tang that is fitted into the handle of horn or wood. The drawing is done by a small trip hammer which strikes 300 to 400 blows a minute. Then the bolster or shoulder is made by pressing with a fly-press the part of the steel that remains between the blade and the tang. A cutting machine then gives the blade its final form, and various reheatings or cold hammerings restore to the steel its original physical qualities. As a fact, in the course of stamping the crushed metal loses its homogeneity, so that, in order to make a good knife, it is necessary to use special steels from which the blades are forged by hand in the old way, or by the aid of suitable machinery to multiply the blows of the hammer as a blacksmith does. These methods, though, demand a large expenditure of time and energy, and it is, therefore, better to use a rolling process, by which, after a single heating, the workman in drawing the metal causes a regular displacement of the mass with a minimum of effort and without altering the internal structure of the metal. The principle of the various machines is that two cylinders each having a concave die of half the thickness of a knife give to the blade its general form. The workman inserts the steel rod, cut to the desired length and heated red hot. It comes out on the other side transformed into a blade. Unfortunately these machines are expensive; new cylinders are frequently needed and the price of renewal is high while, in addition, they are suited only to a single fixed model. Consequently, a new rolling machine has been lately invented, consisting of one small unstamped cylinder and a plate carrying the matrices of the different blades and traveling on a carriage formed as a slide bar. The movement of the carriage is produced by means of a screw or a rack bar, or a connecting rod and eccentric, while the rotation of the cylinder is caused solely by the adherence of the objects to be rolled. The cylinder is fixed on an adjustable shaft which can be regulated according to the thickness desired. The steel cylinder lasts indefinitely, and it suffices to true it each week with an emery wheel. As to the matrices, which vary with each model, they bear five rehardenings easily, and can strike off 500,000 blades before being worn out.

Whether the blade has been made by hand or by rolling machinery its surface is rough and the contours inexact. It is, therefore, necessary to go on to the smoothing down which was formerly done with a file, but is to-day executed by special cutters which give it the final form. On leaving these machines the blades receive a preliminary grinding in order to equalize the thickness of the cutting side. This whitening reduces the later work of the grinder after the blade is hardened. It also facilitates the stamping of the mark which is made by placing the tool engraved in relief on the blade, lying flat on an anvil, and striking a heavy blow with a hammer, which stamps the mark on the blade.

Fine blades are still hardened as in the eighteenth century. They are first heated with charcoal to a clear red and then they are quenched in water. After this they are again slightly heated to temper the steel and to give it elasticity, and when the metal becomes straw-colored or blue, according to its quality, the tempering is checked by quenching the blades again in cold water. The blades of moderate priced articles are hardened in the following manner. A fireclay crucible filled with lead is set in an ordinary furnace, and as soon as the metal boils the workman seizes in succession with pincers each blade to be hardened by the tang and plunges it up to the bolster into the crucible. As the blade is thin it quickly acquires the temperature of the lead, the workman draws it out and immediately plunges it into a pot of colza oil, which may be seen to the right in one of the illustrations. An iron grating on the top of the pot stops the blades by their projecting parts and the number of its interstices for blades is just sufficient to keep the temperature of the oil bath at the right point. The hardening has much influence on the value of the knife, for it gives resistance, hardness, and elasticity to the steel. As, however, hardening rarely gives these three qualities at the same moment to steel, it is necessary to repeat the process several times and the skill of the workman plays a large part in the final result.

During the tempering the metal passes successively through characteristic shades of fire colors. To obtain a very tough steel it is tempered to a deep blue; if it is to be more hard than tenacious, to a straw color, etc. For example, knives with strong blades are heated to a copper red, bistourys, and penknives to an orange yellow, razors to straw color. Finally, certain articles, as lancets, demand special care and need to show several shades at the same time when in the fire. Thus a fine knife will show in the tempering the color of water, violet, and copper red in succession from the back to the cutting side.

Next comes the grinding, the beginning of the sharpening which gives the cutting edge to the blade. As was said in the early part of this article, it is done by grindstones generally made of Vosges sandstone. The stones are 1.33 meters in diameter and 0.15 meter thick and turn at a moderate velocity in a trough constantly filled with water. After it has sharpened 600 to 700 dozen blades the grindstone is worn out, being reduced in diameter to 0.66 meter.

The sharpening, which follows the grinding, gives the edge to the cutting side, and is done by hand on whetstones of different kinds according to whether the knives are large (quartzose sandstone), or the blades fine (greenish close grained schist).

As has been already said, grinding is a fatiguing operation for the workman, as their task is carried out in a humid atmosphere full of metallic dust. At Châtellerault the grinder stands. In whatever way it is done the work is laborious. Efforts have been made to find mechanical methods of doing this work, but no grinding machine that has been devised up to now appears to have solved this difficult technical problem. One patented some five or six years ago seems, however, to be an ingenious device, although up to the present not largely in use. This machine requires only two workmen, and when once regulated sharpens 200 to 300 pieces per hour. After it has sharpened 100,000 blades the grindstone of the machine has to be replaced.

Be that as it may, it is necessary to smooth and polish the blades in order to give them fineness and metallic luster. This work is usually done on wooden wheels covered with felt or with pieces of buffing leather coated with emery, and driven at an average speed of 2,000 to 2,500 rotations per minute. They are partly inclosed by a horse which serves as a seat for the workman and protects him from the flying dirt, and they are able to execute several kinds of operations. One man first polishes the bolster, another the back of the blade, a third the blade, and at this point the polishing stops for common cutlery. For more carefully made articles the work is carried farther with polishing wheels or laps covered with leather and coated with tin putty or crocus. Sometimes certain manufacturers at Châtellerault send the blades to another special polishing wheel coated with a mixture of wax and flour emery. Lastly, cutlery of complicated form is polished by wheels equipped with brushes soaked in a mixture of emery, tin putty, and crocus.

The blade of our knife being now completed and brilliantly polished, let us examine the manufacture of the handles of ebony, or other rare woods, bone, horn, and ivory.

The work commences by cutting up the crude material with a circular saw into pieces of the desired length and thickness, then into roughly shaped handles, which are trimmed by planing. Each handle is then put successively into a tool which presents its end to a special cutter fixed in a rapidly rotating shaft. After this the handle is set on a planing machine with a cutter appropriate in form to the shape of the future knife. Then an open guide presents the four sides successively to a tool which, revolving below the handle at a speed of 2,500 revolutions per minute, ornaments the sides with more or less artistic chasing. The place for the ferrule is made on a lathe, and the piercing of the hole to receive the tang of the blade is also thus done. Finally, the handle is polished with various kinds of wheels or laps coated with a mixture of pumice and oil. Pearl handles, though, are dressed by hand after they are sawn out.

We have now the two essential parts of the knife: the blade and the handle. All that is now lacking is a ferrule of German silver or silver to unite them. The band ferrules of common knives are generally made from strips of German silver rolled and grooved. The strips are divided into pieces of the desired length, and the two ends are brought together and soldered.

For finer cutlery the ferrules are stamped out as follows: The German silver at a thickness of 2½ tenths of a millimeter is cut into strips and pieces suitable to make half a ferrule. Each of these pieces is then put under drop-hammer, the matrix of which imprints the desired ornamentation on it, and then a cutter removes the unnecessary metal. The ferrule halves are reheated and prepared for the soldering by passing the two faces flatwise against a Lombardy stone in order to smooth them. The workman then unites them by twos with a very fine wire and fills the joints with solder mixed with powdered borax. He then places the ferrules on a long wire spit which he sets on a grooved board arranged to receive three or four dozen spits and places them in a furnace. When one side of the ferrules is welded, then the other is done, after which they are cleaned off with nitric acid and vitriol. Lastly, the seam is smoothed down with a small file and the ferrule is polished with a brush.

The making of silver ferrules does not differ greatly from the manufacture of German silver ones. It is now necessary to assemble the three parts (blade, handle, and ferrule), the manufacture of which has just been described.

First, the fitter puts the ferrule on the handle, then, according to the particular case, he enlarges the opening in the handle or reduces the tang of the blade to make sure that the bolster has a true bearing. Another workman then seizes the trued knife, draws the blade from the handle and puts the tang of the blade to heat on a charcoal brazier. While this is heating he fills the hole in the handle with a cement made of resin and powdered brick. He then forces the tang, which is red hot, into the handle. The cement melts, and after the work has cooled a third workman rubs the ferrule clean and sends the knife to the polisher, who puts the final polish on the handle. The knife now goes to the filer, who removes the overthin part of the cutting edge, which by doubling over, would prevent the edge from cutting. This last operation, which is at least the thirty-eighth phase of the manufacture for ordinary articles, is done on a Normandy stone, and is repeated on a Lorraine stone with a finer grain.

The manufacture of spring knives closely resembles in its main outlines that of table knives except in the making of the handle. The metal pieces or scales which form the handle are made by a punching machine and are finished by filing. The assembling consists in uniting these scales and the spring by two rivets fastened in tight, and the blade is introduced between the two scales. The head of the blade is fastened by means of a rivet, to which a little play is allowed. As the scales are generally covered by plates of other material the latter are set on before the assembling.

It should be said in closing that though knives are an object of primary necessity they are made only in a few centers. Thiers, Nogent (Department of Haute-Marne), Châtellerault and Langres in France, Sheffield in England, and Solingen in Germany, flood with their products all the markets of the world, notwithstanding the enormous customs duties, sometimes over 50 per cent of the value of the objects as in the United States, and rising even to 975 francs per 100 kilogrammes for fine cutlery in Russia. Up to now the English and Germans have been much more active than the French and have secured, to the damage of the latter, the larger part of the business throughout the world. Before the present war Solingen with its suburbs formed a town of over 150,000 inhabitants engaged almost solely in the cutlery trade. Its annual output was valued at more than fifty million francs, of which it exported to the value of thirty million francs. It had the audacity to send its knives to Thiers, whence they returned bearing the justly renowed Auvergnat stamp, so as to compete more easily with French articles. It is to be hoped that the French will now be wise enough to protect themselves against such proceedings.

Sheffield, which turns out an article of good quality, manufactures annually, for its part, cutlery to the value of 40 million francs, of which it exports to the value of twenty million francs. The factories of Thiers and Châtellerault, therefore, ought to adopt modern equipment in order to battle with success against such formidable rivals.

Old English Seals

An examination of the old wax seals on documents in the British Public Record Office show that those dating between the thirteenth and eighteenth centuries have a composition almost exactly like modern sealing wax. A specimen of the Great Seal of 1530 was found to be composed of pure beeswax; while two seals on documents bearing dates 1399 and 1423 were of beeswax that had characteristics more nearly like the Indian than European article.

The Reaction of the Planets Upon the Sun—I*

Influence of the Earth and a Study of Sun Spots

By P. Puiseux,[1] Member of the Institute, Astronomer at the Paris Observatory

THE popular preconception that the earth, with the sun rotating about it, was the center of the universe, was overcome only through the persistent efforts of astronomers and physicists. We will not here review these memorable discussions, but will note merely the result. Everyone capable of connected and geometrical reasoning will become convinced that the position of the earth, face to face with the sun, is that of a humble satellite, and that our globe, forced to escort our daytime star in its mysterious course through space, receives from this star its law of annual movement and at the same time its indispensable ration of heat and light.

Going from one extreme to another, the sun was believed to be independent of the relatively minute planets which it carries along with itself. It seemed that a fictitious observer, placed at its center or on its surface, would have no occasion to suspect the existence of other celestial bodies. Further protected against any perceptible action from the stars by their immense distance, the sun must lavish its splendor, with no pay in return, and follow unperturbed its undeviated path through space.

THE INFLUENCE OF THE PLANETS ON THE MOTION OF THE SUN.

This conclusion was in some respects too radical. An account of this matter could be rendered only when the penetrating genius of Newton showed that the curved trajectory of a projectile, the revolution of the moon about the earth, and the revolution of the earth around the sun were three manifestations of the same law. This law holds everywhere. Further, it is not a special privilege of the center of any system. The bond exists, real though slight, between any two particles whatever. The sun, as well as the humblest planet, because of this bond, must undergo periodic variations in its speed as well as in its shape.

Have we to-day at our disposal sufficient delicate means of observations to detect these changes? In Newton's time such means were probably lacking. The caprices of our atmosphere furnished a ready explanation of the apparent fluctuations in solar radiation. The spots had been observed on the sun's disk, sometimes few, sometimes many, but no law had been assigned to them. Further, the traditional fixity of the constellations led to the belief that the sun maintained a complete immobility with reference to the stars.

But the problem plainly stated aroused new attempts at its unraveling. Bradley, a fellow countryman and a disciple of Newton, showed that much greater precision could be obtained in the measures of the angular distances of the stars than had before been gained. Less than a century later, W. Herschel could affirm that the constellations do alter their form, and the best determination of these changes may be explained by attributing to the solar system a regular rectilinear motion. The ambition of astronomers, increasing with success, tries to-day to show that this movement is not rigorously uniform, and even though shielded from the action of the stars, pays tribute to the universal attraction in periodic oscillations.

It is pretty safe to predict what will be the most marked of these oscillations. It is not the center of the sun itself which possesses the uniform rectilinear motion, but the center of gravity of the system formed by the sun and all the planets. The oscillation would be small if only the earth need be considered. There is, however, a giant planet, Jupiter, whose mass exceeds that of all of the other planets taken together and is nearly 1/1,000 that of the sun. Describing its orbit at the rate of 12 kilometers per second, Jupiter forces the sun to rotate about an imaginary center with a velocity a thousand times less. This is apparently a very small amount, but not at all negligible with respect to the velocity of translation of the solar system, which is 20 kilometers per second. Consequently, the speed of the solar system toward a point in the constellation Hercules is sometimes accelerated, sometimes slowed, by one part in one thousand in an interval of 6 years.

Very few of the stars are near enough to us for the parallactic displacement relative to the more distant stars and due to this motion of the sun to be appreciable in 6 years. Consequently, to measure 1/1,000 part of this displacement is beyond the resources of precise astronomy. We may be pretty sure, though, that some day we will thus obtain, at the same time with a measure of the mass of Jupiter, a satisfactory new confirmation of the principle of the universal attraction of gravitation.

Meanwhile help comes in another way. What the micrometer for a long time will probably be unable to give, the spectroscope is always furnishing. Although the variation of 30 meters per second, which we wish to detect in the motion of the sun, requires years to change sensibly the apparent position of a star, it takes only a moment to alter the quality of its light. Whatever the distance, the light waves will come to us sometimes more frequently, sometimes less; their path through a prism will consequently be found altered and the fine metallic lines of the spectrum recorded by a photograph will be displaced relatively to those of a stationary source, such as an electric spark used for comparison.

The earliest happy applications of this principle were due to Huggins and to Vogel. It was used to separate numerous double stars composed of pairs of suns so close to each other and so distant from us that each pair appeared as a single star. But the brightness of each was sufficient to record a spectrum and the relative velocities were sufficiently variable so that two spectrum lines of the same chemical origin separated periodically. Subsequently another class, yet greater in number, was found in which the spectrum lines were not doubled, but showed a periodic oscillation. In this case we may suppose that one of the two stars, while not bright enough to register its spectrum, is yet heavy enough to sway its associate. The period is usually several weeks or days. The displacements of the lines correspond to velocities of the same order as those of the planets, from 10 to 100 kilometers per second. Because of the extreme accuracy and care in the use of spectroscopes, certain astronomers can now measure velocities to a fraction of a kilometer.

The time will come when pairs like the sun and Jupiter can be detected, however distant they may be, provided only that the principal star is bright enough to record its spectrum. Campbell, who is the leader in this class of research, estimates that on the average one star in three will be found spectroscopically double. It is very probable that even more stars are double since we can see no reason why a planet like Jupiter should be exceptional. We may predict that all stellar spectra will be found thus variable even after correcting for the orbital movement of the earth. We may then gather photographic evidence of the existence of planets about the stars as well as the periodic oscillation of our sun due to Jupiter. The earth, of course, will produce a similar effect only less in amplitude and period. But who would dare to put a limit to the skill of our opticians or the patience of our astronomers in a path so definitely marked out?

THE PLANETS AS THE CAUSE OF THE SOLAR CYCLE.

To find that we disturb the sun is of course something to elate us. We feel perhaps a more tangible satisfaction if we can find that we cause changes in the aspect of its surface, disturbances visible by direct and not indirect evidence in the field of the microscope.

We will now consider a deforming action dependent also on Newton's law but of a differential nature and consequently proportional to the inverse cube instead of the inverse square of the distance. This difference helps to compensate for the inferiority of the mass of the earth with reference to the greater planets and gives it a chance for an honorable rank in this contest.

We have under our eye an encouraging phenomenon. The attraction at the surface of the earth due to the sun is but a small fraction compared to the weight of a body here, and the yet feebler attraction due to the moon can not lighten a body by 100/1,000 part of its weight. Yet we see the moon exerting this power and indeed with three times more strength than is felt from the sun, in deforming our globe. This action can be detected upon the atmosphere, the oceans, and even the solid crust of the earth. The seas, however, are what render it most evident to our eyes. Under favorable conditions, for instance, in the Bay of Mont St. Michel, on the French coast, we see the sea following faithfully the passage of the moon across the meridian. The sea's level changes at the flood some 20 meters in a few hours, displacing the shoreline several kilometers. The work thus developed, if we could only put it to use economically, would be enough to render useless all our oil wells and all the engines in the world.

We may find that no planet is as favorably situated to trouble the sun as the moon is the earth. But perhaps we should not be so exacting. We see upon the sun no such liquid seas which might be made to extend or contract their domains. The weight there to be conquered is great, 27 times greater than here. Despite that, we see chances that the sun may react as actively, or even more actively, than the earth, under the action of a distant body. We are indeed led by several converging paths of reasoning to think that the surface layers of the sun are to a great depth formed of extremely tenuous mobile matter, little subject to the action of weight and all ready, consequently, to obey the least force.

A first piece of evidence along this line is the development of spots, rents which seem to appear in the luminous veil of the solar surface, reaching in a few days an extent of 10, 20, or 30 thousand kilometers and disappearing with equal rapidity. In the spectrum of these spots there is an increase in the number and intensity of the absorption bands, leading us to think that various metallic molecules of considerable atomic weight are spouted out in torrents, carried along by currents of lighter hydrogen.

More impressive yet is the appearance of protuberances—clouds which develop and remain at heights where they could not be sustained by the dense and refringent atmosphere. Much less bright than the disk, they have a special spectrum and during total eclipses are the principal source of light. We can now photograph them at any time about the edge of the disk by an ingenious method devised in 1868 by Janssen and by Lockyer and since singularly perfected. On many occasions we have been assured by incontestable evidence that protuberances can mount in a few hours in the form of vertical jets, narrow at the base to prodigious heights —50,000 to 100,000 kilometers or even more. Generally, however, before attaining such heights the protuberances expand into sheaves or stratified layers. At times they seem to be the seat of violent explosions, are scattered, and disappear very quickly. The spectroscope shows us that calcium vapor, despite its atomic weight 40 times heavier than that of hydrogen, rises very high in the protuberances. The displacements of the spectrum lines also furnish confirmation of the enormous velocities (100 kilometers or more per second) which the deformations of the contours suggest.

Total eclipses, during which protuberances first attracted attention, are even now the only occasions when we can see another interesting phase of solar activity—the solar corona. Sometimes it appears as a halo somewhat equally distributed around the disk, at other times as gigantic streamers stretching out distances several times the diameter of the sun. The forms of these rays indicate that the matter of which they are composed shows no haste in falling back into the sun. This matter is evidently very sparse and has very little absorptive action on light, for, despite its irregular distribution, it causes no difference in the appearance of the various parts of the disk. Its mobility must be very great since in the interval of two or three years between eclipses its structure completely changes, as our photographs assure us.

Spots, protuberances, and corona are subject to a great variation which takes place regularly about nine times in a century. After a period when the sun's disk appears entirely immaculate, spots re-appear in both hemispheres at latitudes from 20 degrees to 30 degrees, then, always increasing, they invade the equatorial regions, becoming at the maximum 20 times more numerous on the average than in a minimum year. Then, as the decline commences, the numerical predominance, which the Northern Hemisphere at first seemed to show, passes to the Southern Hemisphere. The spots first disappear in the high latitudes and then diminish all over the sun.

The protuberances pass through a similar cycle, except that during the period while their number increases their mean latitude tends to increase in each hemisphere. Toward the epoch of spot maximum, and only then, it is not rare to see great protuberances even near the poles, where spots never appear.

The corona during the same period always undergoes a definite evolution. Toward the epoch of sun-spot minimum the polar rays are fine and vertical like the bristles of a brush. The jets in the middle and mean latitudes are much longer and bent toward the Equator. At the maximum period there is little difference with the latitude. During the transition years the poles and the Equator are almost clear and the rays are developed only in the middle latitudes, giving the whole a rectangular appearance.

The more we reflect upon these facts the less are we led to regard the sun as a monarch, inaccessible, and shut up in a tower of ivory. It, like the earth, must have seasons connected with the revolution of the planets and tides connected with its own rotation. To sift

*Lecture delivered at the Conservatoire des Arts et Métiers, February 23rd, 1913.

[1] Translated from *Revue Scientifique*, Paris, May 3rd, 1913, in the Annual Report of the Smithsonian Institution.

out at least the more active of these external influences is a legitimate task, even though it is not an easy one.

First, do we find one or several bodies which could be held responsible for a cycle of 11 years? The stars seem to be beyond consideration, since in that period there is no appreciable change in their linear or angular distances.

We could, as did John Herschel, blame one or several swarms of meteors, imagined for the purpose. Describing very eccentric orbits, they might graze the surface of the sun, causing the spots. Suitably choosing their revolution periods, inclinations, eccentricities, and the distribution of the matter in their orbits, we could explain the phenomenon in all its details. We must confess that the permanence of swarms of meteors put every 11 years to such a violent test does not seem probable. There is no doubt that meteors fall into the sun in great numbers. But we have no direct proof that this happens periodically and so as to produce visible effects. Such proof we feel that we must demand for this very supple and convenient hypothesis. As these swarms have not been detected, we must leave them and direct our investigations to the planets.

The most important of these planets brings a coincidence at first sight very seductive. Nearly every 11 years Jupiter, in a determinate sense, crosses the plane of the solar equator; also in every 11 years the numerical predominance of the spots passes from the northern to the southern hemisphere of the sun. The same interval separates the return of Jupiter to its least distance from the sun and the return of the sun-spot numbers to their extreme value.

We must not hurry, though, to sign our victory. It is not an approximate concordance but a precise one which we should demand. The periods in years are 11.86 for the revolution of Jupiter and 11.13 for the sun-spot cycle. For the second period which is less well defined, the incertitude is in the hundredths. For more than a century we have careful records of spot numbers which reappear regularly. Now, in the course of a century the difference of 8 months between the periods brings them from complete coincidence to an absolute discordance. What now remains of our hoped-for proof if the nearest approach of the planet must sometimes condition an increase of spots, sometimes their disappearance?

We may suppose that Jupiter's action, though preponderant, is modified by a somewhat slower disturbing force which increases the interval between successive maxima. But the statistics of the number and extent of the spots, analyzed with the view of finding such a force, assigns to it such a long period that we have no clue as to its origin. *A priori* the most probable disturbing body would seem to be Saturn. It must act in the same sense as Jupiter, although to less extent. The spot maxima or minima should be particularly pronounced when the two planets are in conjunction with the sun—that is, every 20 years. Here again the evidence is negative.

We get an even less favorable answer from the rest of the planets. Either their revolution periods are too short to render an account of an 11-year fluctuation or their distances too great for their action to be sensible compared with that of Jupiter.

THE PLANETS AS A DISTURBING ELEMENT IN THE SOLAR CYCLE.

No planet then, or combination of planets seems to be the principal cause of the solar cycle. We may, however, suppose that this or that planet may for a brief time trouble the cycle by rendering the distribution of spots irregular in longitude.

The sun rotates with reference to the fixed stars once in 25 days. The planets revolve about it in the same direction, but more slowly. Therefore, to an observer on the sun, the successive passages of a planet over his meridian occur in periods somewhat longer than 25 days, tending to approach this (sidereal revolution) as the planet's distance increases. This is called the synodical rotation. That corresponding to the transit of the earth is 27.35 days.

Considering now the extreme mobility of the solar surface, we will see whether each planet does not produce a tidal wave which passes over the sun's surface with the corresponding synodical rotation period and capable of producing visible disturbances.

According to the elementary law of Newton, the relative importance of the tidal waves for the various planets is given by what we may call the deforming factor, the product of the mass by the inverse cube of the distance. If we make the value of this factor unity for the earth, the mean values for the planets are as follows:

Mercury	1.04	Jupiter	2.20
Venus	2.09	Saturn	.106
Earth	1.00	Uranus	.019
Mars	.03	Neptune	.001

We see that the most active cause for a tidal wave lies in Jupiter, followed closely by Venus. Mercury and the earth come next, the remaining planets being much less active.

Although the earth comes only in the fourth rank, we will consider it first because we are better situated for examining its effects. At each instant we can consider the sun as divided into two equal hemispheres, one visible, the other not. The limiting meridians turn uniformly over the surface of the sun in 27.35 days, the synodical period.

Let us first suppose that the earth has no physical influence on the development of the spots. The ratio between the total sun-spot areas in the two hemispheres may happen to have any value whatever; but the mean value taken over a long period of time embracing many synodical rotations, say for a whole solar-spot cycle, should differ very little from unity.

We can not at any given moment count or measure the spots on the invisible hemisphere. But we can count the spots which appear on the eastern border and compare these with those which disappear in the corresponding time limit at the western border. The ratio of the two numbers would have a tendency to surpass unity if it is at a time of decrease in spots and to be less than unity if in the increasing phase. But taken over a whole cycle, the mean value should differ very little from unity.

Now let us suppose that the earth does have a physical influence, for instance, to fix our attention, that the presence of the earth above the horizon of some point on the sun favors the development of a spot at that point. As this development is certainly not instantaneous, any more than is its disappearance, more spots will be born in the visible hemisphere than in the opposite one. Consequently, more spots will disappear over the western border than appear at the eastern. The inverse inequality will be observed, provided we observe over a sufficiently long period, if the presence of the earth causes the disappearance of spots.

Instead of comparing the eastern with the western border we could compare the two halves of the visible disk, the right with the left, and the result would be equally decisive. Practically, if the action of the earth on the solar surface is real, the action will necessarily take a certain time to become manifest. Considerable masses must be moved, masses doubtless subject to interior friction. It is so relative to terrestrial tides which at any point of the earth suffer a variable retardation, but always very marked with reference to the passage of the moon over the meridian. If the earth has no influence, the two halves—the right and left—would, if considered over a sufficient time, show the same number and same area of spots. If the earth has a real influence there will be found a persistent and systematic inequality.

RESEARCHES OF MRS. MAUNDER, 1907.

Mrs. Maunder undertook to answer this question, utilizing the photographs due to a co-operation of English observatories for the interval 1889 to 1901, extending from one spot minimum to the next. At the beginning and the end the sun seemed absolutely free from spots. In every instance the rare survivors which could be found at the beginning and the end of the period upon the visible hemisphere could not vitiate the conclusions derived from all the observations.

The tables obtained at Greenwich comprised—

(1) The positions and areas of the groups for each day.

(2) The history, day by day, of each important group; the areas are expressed in millionths of the visible hemisphere and are corrected for the effect of perspective; the mean duration of a group is about 6 days; 2,870 groups were studied.

Mrs. Maunder divided the visible hemisphere at each instant into 14 vertical zones, each 13.2 degrees wide and numbered in the inverse order of their appearance. For each zone and the entire period the sum representing the area of the spots was made. These results were compared for zones symmetrical to the central meridian. There was thus made manifest a systematic variation from two points of view:

(1) Despite the perspective correction, there was a constant progression on each side in passing from the limb to the central zone, as if the perspective correction had been insufficient.

(2) For each pair of zones there was a constant decrease in passing from the eastern to the corresponding western zone. The same thing was noted when in a similar manner the northern and southern hemispheres were treated separately.

Various reasons make the measures on the extreme zones less trustworthy, but even if we omit them the same conclusions result. If refraction in the solar atmosphere plays a part it would unduly enrich the extreme zones. Accordingly, if a correction is made for it, it but increases the first anomaly. Neither anomaly can be due to errors of observation or reduction.

If we do not like this process of treatment we need not depend upon the areas of the spots, but count simply the number of groups visible in each zone, omitting those of long life which necessarily appear in both halves. Here again, for all pairs of zones, the eastern one shows a greater number than its corresponding western one.

We next ask whether there is, either in the visible or in the invisible half, an habitual and systematic excess in the number of spot births over deaths. *A priori*, it seems as if it must be so for one or the other hemisphere during the phase of increasing spots, but that an equilibrium must be established when a complete cycle is considered.

To throw light on this point Mrs. Maunder associated on each half of the disk the two extreme zones and compared the number of groups of spots which had been seen in each of the two double zones. The predominance was clearly in the eastern pair. There are throughout a cycle more spots seen near the eastern border, and consequently for the whole visible hemisphere and whole cycle there is an excess of disappearances over appearances of spots. The opposite must hold on the invisible hemisphere, since at the beginning and end of a cycle the sun is entirely free from spots.

Neglecting the extreme zones, where the disappearances may be more subject to error, there was obtained for each zone the number of spots which were seen in it for the first time and the number seen in it for the last time. The following result was noted:

As we go from east to west, crossing the visible hemisphere, there is an almost constant diminution in the number of spot appearances over a whole spot cycle and as nearly constant and even greater augmentation in the number of disappearances.

When we compare two symmetrical regions of the disk, the number of births found in one is generally smaller than the number of disappearances in the corresponding region on the other side of the central meridian.

If we were dealing only with numbers, the departures noted might be considered as resulting from a psychological cause. It is probable that there is in an observer a certain, perhaps unconscious, laziness which keeps him from recording new appearances and prolonging old spots unless absolutely necessary. It is always more agreeable to register a disappearance which simplifies work rather than an appearance which augments it.

Thus, when a new small spot appears for the first time, there is a tendency to include it among those already noted rather than to regard it as an advance guard or germ of a new group. If the first impression is wrong, then there results an unjustified diminution of births in the visible hemisphere.

In a similar manner, if a small group approaches a more important group, either by expansion or derivation, there will be a tendency not to consider it separately and to cease counting it as soon as the separation between it and the larger group ceases to be distinct. We are thus led to credit fictitious disappearances to the visible hemisphere.

Both these considerations lead us to record more disappearances than births. But these errors in counting do not explain why the total area of spots is regularly found greater in the eastern half of the visible disk. Considering all of Mrs. Maunder's results we are led to think that the presence of the earth above the horizon of a place on the sun tends to make spots there disappear.

(*To be concluded.*)

Selenium Cell Making

WITHIN a late period almost all selenium cells are made by using a flat slab of insulating material with a double winding of rather fine platinum wire, upon which the selenium is spread. While many commercial cells use steatite as a base, amateurs will find this material not only hard to obtain, but very difficult to work, owing to the great hardness of steatite. A good substitute is slate, in the ordinary thin slabs, which can be easily sawed in small oblong pieces, and then these are scraped down with a knife so as to give a somewhat elliptical section in order to have the wire lie on well, the edge being rather fine, but not enough so to cause breaking. Great care should be taken to have a clean fresh surface and not to impregnate the very porous slate with impurities by handling with the fingers, which would spoil the insulating properties. One of the main things in a cell is to have the wire mathematically spaced. Grooves are cut along in the edges only (not on the surface), but it is out of the question to make measured marks by the eye, or to cut such grooves other than by machine. Of course a skilled person could easily design a cutter wheel machine for such purpose, but any amateur can make a sufficient cutter by mounting a flat wood block or cell-holder to travel along between two guides (rulers). At one end of the main base is fastened a small block carrying an inserted fixed nut in which moves a piece of threaded rod; on the outer end of the rod is a large wood disk, while the inner end pushes the carriage along upon turning the screw. The cell is clamped on the block carriage. Half a turn of the screw thus drives the carriage along say one millimeter each time. The edge of the cell projects over the carriage. Cutting could be done by a small wheel at one side, but it is sufficient to mount a small fixed block very near the edge of the slate and use it as a guide for a flat saw blade, by which very accurate cutting can be done.

Gyrostatic Action—II*

As Applied to Torpedoes, Submarine Craft and Aeroplanes

By Jas. G. Gray, D.Sc., F.R.S.E.

Concluded from SCIENTIFIC AMERICAN SUPPLEMENT No. 2045, Page 173, March 13, 1915

ATTENTION is now directed to Fig. 7, which shows a new form of stilt top. A gyrostat is pivoted within a structure terminating in two stiff legs. When the feet of the top are supported on a table, with the plane of the frame vertical, the line of the pivots which carry the gyrostat is sloped to the vertical, and with the direction of slope indicated it will be seen that when the plane of the fly-wheel coincides with that of the frame, the weight W is constrained to move, relatively to f, in a circular path whose highest point coincides with that occupied by W in the figure. Thus in the position

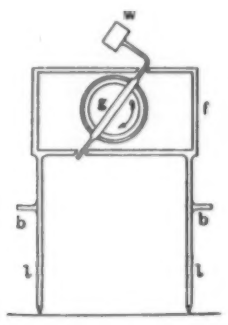


Fig. 7.—Stilt-top.

shown the gyrostat, in consequence of the presence of the weight, is unstably mounted on the frame. Further, the frame is unstable about the line of contact of the feet with the table. Thus the gyrostat possesses two instabilities without rotation of its fly-wheel. If the wheel is rotated rapidly in either direction, and the top placed on a table as described, and left to itself, it will balance on the table. It will be readily seen, however, that the stability is not true stability; the balancing action is accompanied by gyrostatic oscillations of increasing amplitude.

Now let the top be spun in the direction indicated in the diagram, and set up in the fork and pedestal mounting (after the manner of Fig. 2) with the frame and fly-wheel in the same vertical plane. As before, the experimenter operates the fork. With the direction of spin indicated, tilting of the frame to one side of the fork causes the weight W to be carried over to the other side. Now, let a side weight W^1 be attached to the frame f. The gyrostat precesses on the frame bearings, and W is carried over to the side of the frame remote from the attached weight W^1. Let the fork be turned by hand in the direction in which the gyrostat precesses, so that it follows up the latter. Providing that the turning of the fork is so regulated that the frame does not overshoot the gyrostat, the latter will continue to turn on its bearings. It is to be observed that at any instant the acting tilting couple is the difference of the moments about the fork axis of the side weight W^1 and W respectively. The effect of turning the fork is to diminish the moment due to W, and the precessional motion is maintained. This action has

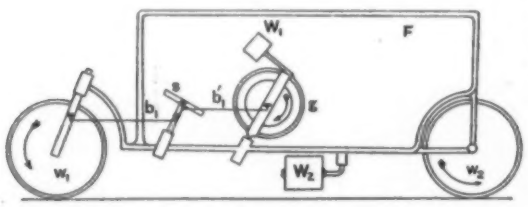


Fig. 8.—Gyrostatic motor-car with electro-magnetic steering device.

been utilized by the author on bicycles and motor cars.

Fig. 8 is a diagrammatic representation of a large gyrostatic motor car constructed on the above principles. The car is entirely stable when moving in the forward direction. It will be seen that the gyrostat stabilizes the car, and at the same time presides at the steering wheel.

The function of the weight W_2 is to apply the necessary tilting couples. W_2 is an arm which is rotated about a vertical axis by means of a small geared electric motor. This motor car is capable of being operated by wireless transmission of electricaf action.

It should be noticed in the case of this motor car, as well as the one previously described, that the gyrostat cannot positively lose control. The frame is continually following up the gyrostat, and hence the displacement of the axis of the fly-wheel from the position in which it lies athwart the car never exceeds 30 degrees.

Fig. 9 shows diagrammatically a gyrostatic device adapted for steering a body stable of itself, such as a tricycle, four-wheeled motor car, or torpedo. The gyrostat is mounted on bearings b_1 b_1 carried by a frame f; it is made azimuthally unstable by sloping the line of these bearings to the vertical and attaching a weight W to the frame of the gyrostat. The frame is carried on horizontal bearings b_2 b_2 arranged on pillars p_1 p_1 attached to the moving body. The frame f is rendered laterally unstable on these latter bearings by attaching to it the weights WW as shown. The gyrostat clearly possesses two instabilities without rotation of its fly-wheel. When the gyrostat is suitably connected up to the steering mechanism these two instabilities give rise to complete stability of the gyrostat when the body is in motion. The frame f may conveniently carry apparatus for applying tilting couples to the gyrostat.

In the construction of wheeled vehicles it has been found sufficient to connect up the gyrostat directly to the steering wheel or wheels. In the case where a steering mechanism, such as a rudder or plane, has to be operated forcibly it may be advisable to multiply up the couple transmitted by the gyrostat. A method which has been found highly satisfactory is shown in Fig. 10. One end of a cord is attached to a point on the frame of the gyrostat. The cord is then passed once or more times round a vertical drum or pulley d_2, then round a drum D carried by the rudder post, then round a drum or pulley d_3, and finally fastened to the gyrostat frame as shown. The two pulleys d_1 d_3, which are of equal diameter, are geared up to a small electric motor; they revolve in opposite directions with the same speed. If the gyrostat precesses one of the cords attached to it becomes taut. A small stretching force in the cord on the gyrostat side of d_1 gives rise to a large stretching force in the cord on the drum side of d_1. If the stretching force on the gyrostat side of d_1 is zero, that on the drum side is also zero. It will thus be seen that a small couple applied by the gyrostat results in the application of a very large couple to the drum, and hence to the rudder.

The rudder is shown connected up, so that when the gyrostat precesses the body is steered up parallel to it —that is, so as to maintain the axis of the fly-wheel transverse to the body. A little consideration will show that a ship or torpedo steered by this mechanism will pursue a perfectly straight path.

In the form of torpedo at present in use the gyrostat is freely mounted on gimbal rings. In the absence of a disturbing couple the axis of the gyrostat will retain its direction in space unaltered. Hence when the torpedo deviates in its path a shift occurs between the direction of the axis of the gyrostat and that of the projectile. The apparatus (as used at present) must be made with great precision: notably the center of gravity of the gyrostat must coincide exactly with the point of intersection of the gimbal axes. If this condition is not fulfilled the torpedo travels a curved path.

The existing type gives very good results over short distances; but a gyrostat freely mounted would be useless in a long-distance projectile, even if a motor gyrostat were substituted for the one now employed. This point is not, as a rule, understood. In a dirigible torpedo, properly so called, the gyrostatic mechanism should be such that the gyrostat is endowed with complete stability. This condition fulfilled, the gyrostat can be caused to bring about turning movements of the torpedo by the application to it of tilting couples.

The construction of a very high-speed, long-distance torpedo, to run completely submerged, propelled by power stored within the projectile, is difficult if not impossible at the present time. But a long-distance torpedo, driven by electric power derived from accumulators, and having speed or from 15 to 20 knots, could certainly be evolved. Such a weapon, with a range of action of, say, 100 miles, and possessing the property that it could be set to travel on a prearranged path, would be a valuable addition to British naval appliances. The torpedo, for example, could be arranged to proceed in a straight path from one position A to the neighborhood of a second position B, and left cruising in that neighborhood.

The progress which has been made in the development of the internal-combustion engine renders possible the construction of a torpedo capable of running at high speeds for very lengthened periods without attention or renewal of fuel. Such a torpedo would, however, not be entirely submerged, inasmuch as an air inlet and an outlet for the products of combustion must be provided. To steer such a torpedo from a fixed or moving station, it would be necessary to connect the torpedo to

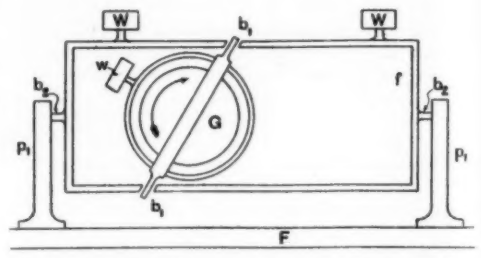


Fig. 9.—Gyrostatic control for torpedo or airship.

the station by means of a pair of fine wires, which could be paid in or out as desired. This torpedo, brought to perfection, would be a formidable weapon with which to fight submarines. The directing of torpedoes by the wireless transmission of electrical action is not practical at the present time. To be effective the sending apparatus at the receiving station would require to be tuned to the receiving apparatus on the torpedo beyond the possibility of interference from without.

The principles which have been explained seem particularly well adapted to give results when applied to problems of aviation. It will be seen that a gyrostat mounted on an aeroplane so as to have two instabilities without rotation of its fly-wheel, and with its axis across the aeroplane, can be endowed with complete stability by causing it to steer the aeroplane. A gyrostat so mounted is available for operating the balancing planes (the planes which control lateral stability) of the aeroplane. Again, the axis of the gyrostat can be placed fore and aft, and the gyrostat is then available to operate the tilting planes (the planes which control longitudinal stability) of the aeroplanes. In order that a gyrostat may be used to operate both the tilting and balancing planes of an aeroplane, it must be mounted on the aeroplane with its axis vertical. To obtain stability of the gyrostat it should be provided with two stabilities with rotation of its fly-wheel, and caused to operate the tilting plane of the aeroplane. It could thus to completely stabilized, and would then be available for operating both sets of planes.

Objections have been taken to the use of gyrostats on aeroplanes, and it is certainly true that there is no point in utilizing gyrostatic action in cases where the desired results can be obtained equally well without the application of such action. But the author is convinced that it is possible to contrive gyrostatic controls for aeroplanes which would be perfect in action, and the utility of such aeroplanes is readily seen at the present time. Aeroplanes and airships, capable of being steered

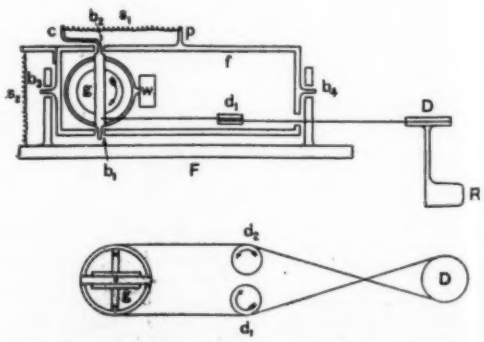


Fig. 10.—Control for ship or torpedo, with stabilized gyrostatic system.

* *Transactions* of the Institute of Engineers and Shipbuilders of Scotland.

in a horizontal plane, lofted or depressed, by means of electrical action transmitted from a fixed or moving station would certainly be of value to this country at the present time. Such contrivances provide a method of fighting Zeppelins and of bombarding an enemy's lines and fortifications.

In conclusion, it might be pointed out that the ship, torpedo, aeroplane, and airship controls which have been described could only be brought to perfection on a large scale as a result of experiment and trial. Such experiments are not possible to a private individual. The principles to be employed have been evolved as the result of much research work. It has been said that the motor-gyrostats required would be difficult to produce. This is not the case. Careful calculations have been made relating to the size and power of the motors, and these would certainly be forthcoming.

There can be no doubt that the present-day applications of gyrostatics to warfare are mere shadows of what is to come in the near future, and this being the case, it is a matter of supreme importance that Great Britain should lead the way in the scientific advancement of the subject. A distinguished gyrostatic inventor from abroad recently informed the author that he regarded Glasgow University as the home of the gyrostat. It is to be hoped that Glasgow University may be allowed to take part in future developments.

Discussing this paper, Prof. Andrew Gray, LL.D., F.R.S., said he supposed he was to some extent responsible for the apparatus and experiments which had been shown. Each of the items which they had seen might form the subject of a separate lecture. It was very difficult to give a full account of so many things. There were a few points about which he might perhaps say a word or two. One was the steering of airships, aeroplanes, and so on. He was not sure that it was made perfectly clear that these could be steered without an aviator or steersman on the machine. They could be steered from any place of observation, and without any trailing wires at all, so that it was possible to send a torpedo to its destination by any desired path, however circuitous, without any risk of loss of life to the attacking party. Also, the range of torpedoes could be immensely increased. At present, if a ship has to discharge a torpedo it has to get fairly close, and in doing so it might be disabled by gun fire; but if the range of the torpedo could be greatly increased the attacking party would be at a great advantage. It was difficult to interest official people in new inventions, and perhaps considering the enormous number of fantastic ideas published, and even patented, that is not to be wondered at. An official was continually guarding his chief from the attacks of people outside—acting, in fact, as a kind of torpedo net for him. In the course of the lecture they had been told more than once that these gyroscopes had two instabilities without rotation. These two instabilities were converted into two stabilities by rotation. But it was not possible to stabilize an odd number of instabilities. For instance, if there were three freedoms they could not stabilize all three; they might stabilize two of them. This was a rather important mathematical theorem. There was still a great deal to be done from the theoretical point of view; but by Dr. Gray's apparatus one did obtain some verification by experiment of the truths of the dynamical results which had been worked out.

Gasoline from "Synthetic" Crude Oil*

Some Remarkable Experiments With Oils and Method of Obtaining an Additional Yield of Gasoline

By Walter O. Snelling

In the course of some experiments more than five years ago, made for a totally different purpose than the investigation of the oil used, I placed a small quantity of a transpareht yellow lubricating oil in a bomb-like vessel and heated it to a relatively high temperature. At the end of the experiment I removed the oil from the vessel and was amazed to find that instead of bearing any resemblance to the oil which I put in, it now had the appearance of ordinary crude oil. The green color by reflected light and the rich red-brown by transmitted light were so unmistakable as to at once lead to further investigation. I subjected the material to fractional distillation, and the surprise which I experienced at the *appearance* of the oil, changed to amazement when I found that it yielded, on distillation, 15 per cent of gasoline and 30 per cent of burning oil, and that its constitution resembled crude oil quite as much as did its appearance. Furthermore, the gasoline and kerosene distillates which it yielded were of of a clear water-white color, entirely without treatment with acid or alkali, and were entirely free from the odor familiar in "cracked" petroleum distillates.

The result of this experiment was quite too remarkable to be credited without further confirmation, and I at once filled the vessel with some of the same oil that I had used before, and again heated to about the same temperature that I had previously used, and for the same period of time. Upon opening the vessel and removing the contents I found, not the material resembling crude oil that I had obtained before, but apparently only the same oil that I had put in, somewhat darkened in color, but nevertheless far different in appearance from the material obtained in the previous experiment.

Evidently some condition existed in the first experiment that had not existed in the second test, and here began a series of tests in which I sought by the change of one variable after another to arrive at the identical conditions which must have existed in the first experiment. Only the fact that the bottle of heavy oil used in the first test was still in its place, and the further fact that I had no crude oil among the materials at hand when I began the experiment—only these facts kept me from believing that I had indeed made some mistake, and that crude oil had in some manner found access to my apparatus.

After many fruitless experiments I learned a fact which should have been obvious to me from the first, but which in the surprise due to the unlooked-for result obtained, had quite passed out of my mind. In my first test, the vessel which I used had contained but a little oil (about one fourth of the volume of the vessel only), and in all of the other experiments I had filled the vessel three fourths full or more in the effort to obtain as much of a yield as possible.

I repeated the first experiment, using the vessel but one fourth full, and heating to about the same temperature, and for the same time as I had done in the other experiments. The result was once more the greenish liquid so familiar to anyone who has lived in the oil fields, and its fractionation again gave 15 per cent of gasoline, 30 per cent of the burning oil, etc.

Apparently some remarkable change must come about in the hydrocarbon molecules, when a hydrocarbon body is heated in a still only approximately one fourth full of oil, that does not occur when the same hydrocarbon is heated under similar conditions, except that a greater proportion of the volume of the still or retort is filled with oil. With grave doubts and fears, I placed in my retort some kerosene. If this water-white material, after treatment, should come out green in color by reflected light, and red by transmitted light, then indeed I would be convinced that I was dealing with a true transformation into crude oil. The experiment ended, I poured out from the vessel a liquid which resembled Pennsylvania crude oil so perfectly that when I placed a bottle of the new product by the side of a bottle of the real crude, it was hardly possible to say which was which, by appearance alone. I next melted some paraffin and placed it in the vessel, and after heating under the prescribed conditions, I poured out a thin fluid, suggesting crude oil in every way, and which on distillation gave somewhat over 15 per cent of a water-white gasoline, free from "cracked" odor, and other distillates in about the same relationship as in ordinary crude oil.

One after another I tried putting all natural hydrocarbons available to me through this process. Vaseline, rod wax, gas oil, fuel oil, and B. S., all these went into my treating vessel, one after the other. They all yielded materials similar in appearance, odor, and composition. From any of these materials I obtained a synthetic crude oil containing around 15 per cent of gasoline, and other distillates in about the same order as are found in typical crude oils.

After many experiments had shown me the exact conditions of temperature, pressure and filling volume of my treating vessel which were necessary to success, I fondly imagined that my troubles were over. I did not for a moment think that human nature would involve greater difficulties than had even the control of natural conditions. Full of enthusiasm, I described the results of my experiments to an oil man, without of course describing the exact process on which I had not yet applied for patent. He listened to me carefully and kindly, but his look of utter unbelief and incredulity was a trifle galling, to one whose life work had been devoted to scientific investigations. Had I been a promoter, selling stock in a gold mine located at Hackensack, or in a diamond mine on the outskirts of Brooklyn, I could hardly have met with less encouragement, or more entire disbelief.

To-day, when processes for increasing the yield of gasoline are being worked on by many investigators and when such lines of work are being encouraged and lavishly supported by a number of oil companies, and are being paid for in many cases with sums far greater than any probable returns, it may be hard for you to realize that only five years ago the shortest cut to suspicion and doubt, from your friends in the oil business, was even to suggest gently in ordinary conversation that perhaps by some method it might be possible to materially increase the ordinary yield of high grade gasoline from crude oil. I tried it a few times, picking out the most kindly and genial of my friends in the oil refining line. They would look, first pityingly, and then suspiciously, and would say "but after you have gotten out the gasoline that is present in crude oil, how do you think that you are going to get any more? Don't you understand that when you have gotten it *all* out why you have gotten it all? What is left then is kerosene, gas oil, or what not. But it is not gasoline."

Only once did I venture mildly to protest. I suggested that possibly, since hydrocarbons were all compounds of hydrogen and carbon, it might be possible to rearrange the atoms in the molecule so as to obtain more gasoline. This view met with some recognition, and I was told that what I was talking about was called "cracking," and that it was thoroughly understood by oil men, and that furthermore, "there was nothing in it" as far as making anything salable as gasoline, as the product would invariably be of bad color, and of an extremely offensive odor.

Slowly I came to realize that the oil industry was not yet ready for any new views as wholly different from their preconceived ideas as these experiments made necessary. So I would go back, for comfort, to the water-white gasoline of 70 deg. B., which I had made from paraffin and from kerosene, from gas oil and from B. S., from fuel oil and from rod wax, and patiently wait for the day when my friends in the oil business would realize that there were a few insignificant things about oil which they did not yet know. For their attitude I could hardly blame them, after all, when I remembered my own doubt when I had seen the results of my first experiments. They had not seen them, and therefore if they doubted, I could at least understand their position, and I am hardly prepared to say that I should have been less doubting than they were, had the position been reversed.

This paper makes public for the first time the results of my experiments, and in presenting it I wish to express my indebtedness to Mr. John T. Milliken of St. Louis, Mo., president of the Milliken Refining Company. He was the first oil man whom I met, who was willing to believe that research could really add materially to the oil man's knowledge. He has generously supported the experiments which I am now reporting, and has supplied the financial help which alone has made this paper possible to-day.

It has long been known that under the influence of high temperature hydrocarbon bodies could be thermolized or "cracked," and that by this method low boiling bodies could be produced from hydrocarbons of higher gravity. Indeed, the commercial use of cracking distillation in petroleum refining goes back from more than half a century, the first observation of such cracking distillation being said to have been made accidentally, in a refinery at Newark, N. J., during the winter of 1861-2.

For thirty years after the discovery of methods suitable to cracking distillation, this method was in common use in many of the principal oil refineries of the world. It was found that by running the stills at a high temperature very considerably increased yields of kerosene could be obtained, and the method was found to be a profitable one from the start, particularly since in the early days of the oil refining industry, burning oil or kerosene was the principal product sought for. The process was also investigated by many able men, and the condition under which long paraffin chains became broken into two or more shorter chains, under the influence of high temperatures were very carefully

* Paper read at the February meeting of the American Institute of Mining Engineers.

worked out, particularly as concerns commercial refining operations.

Accordingly it was only natural that, with the enormous increase in demand for gasoline during the past ten or fifteen years, many investigators should attempt by similar cracking methods to obtain increased yields of low boiling products. When the vapor of kerosene or any heavier oil is passed through a red-hot tube, for example, thermolization takes place with the production of considerable amounts of low-boiling products vaporizing within the ordinary boiling points range of common gasoline. In this, and in many other similar ways attempts have been made both on a laboratory scale, and in large-size commercial installations, to prepare products capable of replacing gasoline. Of the dozens, or even hundreds, of such efforts, few have had even the slightest promise of success, due to the fact that the low-boiling hydrocarbons produced in the manner described are off-color, and possess an odor so pronounced and disagreeable as to greatly limit, if not wholly prevent, their sale. So acute has been the demand for gasoline at times in the past ten years, that it is not impossible that even the color and odor might have been overlooked if the process had given the large yields that were originally hoped for, but in this respect also the ordinary cracking methods have met with difficulties, and in general all these processes produce considerable amounts of tar and coke, that materially cut down their efficiency.

When the limitations of simple cracking of hydrocarbon oils at ordinary pressures were first understood, efforts were made to bring about destructive distillation under increased pressure. Results showing great improvement over those obtained by the simple cracking methods were given by these processes, which seem to have been first made use of by J. Young, and later developed by Dewar and Redwood, and others. Quite recently improved processes of cracking distillation under increased pressures have been used commercially by Burton, and are said to have been so developed as to yield products readily salable as substitutes for gasoline.

Efforts have not been wanting to improve the color of and odor of the light cracked distillates produced by ordinary cracking distillation. Treatment with sulphuric acid and alkali, in the manner commonly used in the refining of kerosene, have the effect of improving both color and odor to a remarkable extent, and by the use of sufficient acid colorless products without bad odor can be obtained, but only by the use of such large amounts of acid as to make the process commercially prohibitive, unless gasoline is selling at quite a high figure. By cracking under increased pressure the amount of acid required for this purification is very greatly reduced, and it is probably due to this fact that the motor gasoline now being so extensively developed by Burton owes its greatest commercial possibilities.

It will thus be seen that I cannot claim to be in any way a pioneer in the production of lighter hydrocarbons from materials of heavier gravity. Hydrocarbons have been cracked and broken up into lighter hydrocarbons of lower boiling point, both experimentally and commercially for a period of over fifty years, and such cracking experiments have been conducted both at normal pressures, and under increased pressures.

Other investigators have also placed hydrocarbon oils within closed vessels and have heated these oils under such conditions to elevated temperatures. In such work Engler, in particular, has made notable contributions to our knowledge of the behavior of hydrocarbons under high temperature and pressure. In these experiments it has been noted that the hydrocarbons have been broken down to lighter hydrocarbons, and that in this way low-boiling oils could be made from hydrocarbons of high boiling point. Apparently, however, the remarkable influence which is played by the ratio of the liquid contents of the vessel to the total volume of the vessel, has been either wholly overlooked, or at least not properly appreciated. It has been wholly through the investigation of the effects of the ratio of the volume of oil, to the total volume of the vessel, that I have developed the process which I am here describing, and which has given the remarkable and unexpected results already mentioned. I believe it is only when these suitable volume relationships are observed, that we can get these results within a range of temperature and pressure adapted to commercial development.

Very careful studies made in my laboratory have now proven that, when a hydrocarbon body, such as gas oil for example, is heated in a vessel which is filled to more than one tenth of its volume with such oil, but such filling is less than one half of the total volume of such vessel, and if then the vessel is so heated that a pressure of say 800 pounds per square inch exists within the vessel, a very remarkable and fundamental change occurs in the hydrocarbon filling such vessel. It is as though the carbon and hydrogen atoms were free to rearrange themselves, and that such rearrangement goes on until a more or less definite mixture of hydrocarbons remains in the vessel. Where the vessel is less than one tenth filled with oil, considerable "cracking" seems to take place and the product is quite inferior. Where the vessel is much more than one half filled with oil, the reaction seems to fail almost wholly, the amount of light products produced being very small. But when the conditions within the vessel, as to amount of filling, and temperature applied, are as indicated above, the carbon and hydrogen atoms of the hydrocarbon seem to rearrange themselves to form crude oil and natural gas.

In this rearrangement, not only are low boiling compounds produced from those of higher boiling point, but even the reverse action takes place. In several tests I have obtained from petroleum products of medium boiling point synthetic crude oils which contained high-boiling ends, whose boiling point was considerably higher than any of the constituents present in the original oil used. Apparently the entire process depends upon certain equilibrium reactions, in which constituents of different boiling point tend to be present in a certain very definite ratio, provided the space relationship within the treating vessel is of the proper order. Solid paraffin of course contains no constituents that are liquid or gaseous at ordinary temperatures, but upon treatment by this process even this solid paraffin is resolved into synthetic crude oil and natural gas, and the percentage of products of each definite boiling point appears to be in a definite condition of equilibrium. If instead of starting with paraffin, we go to the other extreme, and start with kerosene, which is entirely free from heavy ends, we will obtain a synthetic crude oil which is much lighter in gravity than that produced from paraffin, but which nevertheless contains high boiling constituents whose boiling point exceeds by many degrees the boiling point of the heaviest product present in the untreated kerosene. Thus, it will be seen that while this process is primarily one in which heavy hydrocarbons give crude oils containing light distillates (this being the main trend of the reaction), yet the process is so essentially one dependent upon equilibrium, that if high boiling constituents are absent, or present in very small amount, the equilibrium will not be satisfied until additional amounts of these high boiling constituents have been produced as the result of the reaction which is going on.

A residual pressure, after cooling, always exists due to the natural gas formed in the process, and the amount of gasoline in the synthetic crude oil, seems to be very constant no matter what hydrocarbon is taken. It is of course evident to the chemist that natural gas and gasoline contain a greater percentage of hydrogen than do heavier oils, and it is very interesting to note that when the charge which is placed within my treating vessel contains a hydrocarbon deficient in hydrogen, the formation of saturated gasoline goes on just the same, and the synthetic crude oil produced carries a "mud" consisting of the carbon which in the rearrangement has failed to find hydrogen. The gasoline produced from materials even highly deficient in hydrogen is quite normal in color, and does not appear to be in any way like the "cracked" products which are produced by the thermolysis of oil vapors, etc.

The following results of runs made by this process, in one case starting with solid paraffin wax, and in the other case with Oklahoma gas oil, will clearly illustrate all the technical features of the method.

TEST I.

Material used, solid white paraffin. Melting point, approximately 120 deg. Fahr. (50 deg. Cent.). Specific gravity 0.925 (21.5 Be.). 300 cubic centimeters taken. Capacity of treating vessel used, 1,100 cubic centimeters. Heated until pressure of 800 pounds was indicated, then cooled. Pressure of residual natural gas, 130 pounds. Product after treatment, a heavy liquid, resembling "Franklin heavy" Pennsylvania crude oil. Color, dark green by reflected light, deep red-brown by transmitted light. Volume of synthetic crude oil obtained as result of run, 305 cubic centimeters (5 cubic centimeters increase in volume, over the amount of liquid paraffin started with). Specific gravity of this synthetic crude oil, 0.770 (0.51.8 Be.). Gasoline yield, on distilling this synthetic crude oil to 150 deg. Cent., 48 cubic centimeters. Gasoline in synthetic crude oil, 16 per cent. Specific gravity of this gasoline, 0.70 (70 Be.). Color, water-white.

TEST 2.

Material used, Oklahoma gas oil. Specific gravity, 0.850 (34.5 Be.). 300 cubic centimeters taken. Capacity of treating vessel used, 1,100 cubic centimeters. Heated until pressure of 800 pounds was indicated, then cooled. Pressure of residual natural gas, 120 pounds. Product after treatment, a liquid resembling Pennsylvania mixed pipe-line crude. Color, dark green by reflected light, deep red-brown by transmitted light. Volume of synthetic crude oil obtained as result of run, 288 cubic centimeters. Specific gravity of this synthetic crude oil, 0.831 (38.5 Be.). Gasoline yield on distilling this synthetic crude oil to 150 deg. Cent., 40.8 cubic centimeters. Specific gravity of this gasoline, 0.705 (68.5 Be.). Gasoline in the synthetic crude oil, 13.6 per cent. Color, water-white.

It is of course evident that if putting any hydrocarbon through the process described makes it into a crude oil, it ought to be possible to take any hydrocarbon, and first convert it into crude oil by the process described, then remove the gasoline, for example, or any other constituent, from this crude oil by distillation, and then to subject the residue to a repetition of the process. I have done this many times, and have converted paraffin and other petroleum products almost wholly into gasoline and natural gas. I have obtained from paraffin about 70 per cent of water-white gasoline, the remaining 30 per cent representing the natural gas formed by the repeated action of the process, and some free carbon. From fuel oil, gas oil, vaseline, and similar materials, I have obtained from 50 per cent to 70 per cent of water-white gasoline, and samples of this gasoline, even after standing for a year or two, do not discolor, nor acquire an offensive or "cracked" odor. I wish to particularly note that this gasoline, even when produced, was not treated in any way, and has never come in contact with either acid, alkali, Fuller's earth, bone black, or other related materials. In brief, the process which I have described produced from practically any hydrocarbon, a material which resembles natural crude oil, and which gives a gasoline which appears equal in quality and appearance to gasoline from natural crude. Both the crude oil produced by my process, and the gasoline produced from its distillation, possess an odor which is somewhat different from the odor of natural crude oil and ordinary gasoline. This odor, while peculiar and distinctive, is not in the slightest like the odor of "cracked" products, and it is in fact a slightly milder and sweeter odor than that of ordinary oil products. Upon mixing my synthetic crude oil, or the gasoline produced from it, with certain muds and clays, it seems to be altered, and the odor changes and becomes much more like that due to ordinary crude oil. Personally I am of the belief that crude oil in nature has in some cases been produced by some process related to that which I have here described, the effect of the high temperature which I use for a short time having in earth history been produced by very much lower temperatures acting through geological ages. I believe the condition which in my report is represented by about three fourths open space, in nature has had its equivalent in the open space in the sand or other porous rock which has been the repository of the oil, and I believe that natural gas which is so commonly associated with petroleum deposits has had a related origin in nature to that which it has in the process worked out in my laboratory experiments.

The study of the genesis of petroleum is so involved that I do not wish these suggestions to be taken in any way as other than ideas which have forced themselves on my mind after noting the very considerable similarity in appearance and constituents which exists in most of the petroleums of the world (except when a porous cover, or other well recognized conditions have allowed the more volatile materials to vaporize, or other well-known oxidation or other phenomenon to take place), and its seems more than likely to me that any process which in the laboratory will produce materials of such similar appearance and composition from raw products of the most diverse nature, must surely have some connection with the conditions which in geological time have similarly produced from starting out products of many different kinds, a material possessing such well-marked and easily recognized characteristics as petroleum.

One very interesting development in connection with this work has been the effect of small amounts of certain catalytic materials, in facilitating the transformation into synthetic crude oil. The addition, to the oil to be treated, of even a very minute amount of colloidal graphite reduces materially the temperature and pressure at which the process is operative. In one set of experiments, in which a given treating vessel gave synthetic crude oil at an average treating pressure of 850 pounds, it was found that the addition of a small amount of finely divided graphite would lower the necessary treating pressure to 750 pounds, or even to 700 pounds, on somewhat longer treatment. This seems to offer confirmation of the theory which I have advanced, that the entire process is dependent on certain reversible reactions which under the described conditions reach an equilibrium when sufficient time is given. The action of finely divided catalytic materials in increasing the speed of reactions is well-known, and in these experiments their function seems largely to be the increasing of the rapidity of the equilibrium reactions, so that the reaction goes on more nearly to

completion in the very brief time of the test. In my experiments our general procedure has been to heat the treating vessel until the desired pressure is indicated, when the heating is at once stopped, and the treating vessel cooled and emptied. We have found that when, instead of raising the pressure to the desired treating maximum, and instantly cooling the vessel, we raise to a somewhat lower temperature, and maintain this temperature for five or ten minutes, we get practically an equivalent result. Where a catalyst is used, as described, it is possible to use a much longer pressure, and still obtain a normal synthetic crude oil.

These experiments which I have described have been wholly of a laboratory nature, and much work remains to be done in the application of the principles which have been discovered, to commercial work on a large scale. While it may seem to many that the pressures and temperatures employed are so high as to preclude the possibilities of commercial work, yet I do not think this is the case. Processes have been developed abroad, during the past few years, in which ammonia is made synthetically by reactions requiring both higher pressures and higher temperatures than those which are made use of in my present work. As these ammonia researches have gone on, from their laboratory inception to their commercial development upon a very extensive and successful scale, I believe the present process will find similar development comparatively easy. The conditions necessary for successful commercial work are already well known, and involve no engineering features which American ingenuity cannot easily provide, and it is my hope that this process will be soon developed to the point where it will fulfill commercially the remarkable promise that it now seems to offer.

Hydrogen and the Rare Gases*

The series of Friday evening discourses at the Royal Institution was once more opened this year, on January 22nd, by Sir James Dewar, F.R.S., by a lecture on "Problems of Hydrogen and the Rare Gases." Last year Prof. Dewar, discoursing on "The Coming of Age of the Vacuum Flask," and on researches which the use of his vacuum vessels, of charcoal, and other modern expedients had rendered possible, had dwelt on the difficulties of separating and eliminating the rare gases and upon the apparent ubiquity of the lightest of all gases—hydrogen. In the lecture of January 22nd he gave a brief, essentially experimental, *résumé* of further researches, by himself and others, in this field. At 20 deg. Cent. absolute, he pointed out, nitrogen and oxygen were frozen hard, and their vapor tension was so low that they disappeared from the air, leaving only the uncondensable gases, representing about 1/50,000th of the volume of the air, corresponding to a barometric pressure of ⅕ millimeter. When air was deprived of its oxygen by chemical means, and the remaining gases were condensed at 20 deg. Cent. absolute, there should be 29.7 parts per million of uncondensable rare gases left. But much larger amounts were often found; it depended upon the chemical used for absorbing the oxygen. Of these reagents sodium hyposulphate answered best, as it gave 29.7 parts of residual gas. Copper also answered well, yellow and red phosphorous less well; in the latter case the gas, after the removal of the hydrogen in it, amounted to 26.7 parts. Chromous chloride was one of the most striking cases; from 68 to 26,300 parts of gas were found in different experiments, and after removal of the hydrogen, 31 parts remained. The excess of gas was, as already indicated, hydrogen, which found its way into the apparatus with the reagents or by other means.

In order to investigate these problems it was no good to start with large volumes of gases. Sir James exemplified this by showing a skeleton cubic meter with a cubic centimeter inside. Special means had to be devised to experiment with small quantities at the time, to accumulate the effects. The gas absorption by cooled charcoal was very serviceable. Sir James showed, with the help of two barometric tubes, how much more quickly the absorption proceeded when liquid hydrogen was used than when liquid air was used. Studying the air respired by eight different persons in this way, and working again at 20 deg. Cent. absolute, he found from 23 to 52 parts per million of uncondensable gas in the respired air, of which sometimes only two parts, sometimes more than 20 and 30 parts, were hydrogen; the amounts varied with the time of the day and other conditions. Animals also produced hydrogen in similar quantities, and ordinary air contained about 0.8 part of hydrogen per million. The identification of the gases was effected by passing the electric discharge through them and studying the spectra. In a pretty, novel experiment Sir James passed the discharge through a tube containing a mixture of gases, first at too high a pressure to show a good glow; he then touched one portion of the tube with a sponge dipped in liquid hydrogen. So much gas was condensed inside at that spot that the discharge strie of the gases at once began to appear in the other parts of the tube.

Unfortunately, Prof. Dewar proceeded, charcoal absorbed even the rare gases to some degree, and it had its peculiarities. Two tubes were provided with charcoal bulbs, and charged with air; the air in the one tube only had been dried by being passed through liquid air. When the bulbs were afterwards heated (by being dipped into warm water instead of liquid hydrogen), the liberated gas in the one case was essentially oxygen, and in the other essentially nitrogen, the gas extinguishing a burning taper in the latter case. Passing to the occurrence of the rare gases in air, water, thermal springs, sea-water, etc., Sir James pointed to the researches of Moureu and Lepape, according to whom the ratios of krypton to argon, and of xenon to argon, were the same both in air and in the French thermal springs, some of which are very rich in rare gases, while the ratio of helium to argon varied enormously; that might be connected with a radioactive source of helium. As regards the proportions of these gases, city air contained 22.5 parts per million of helium and neon and 2.6 of hydrogen, country air similarly 22.8 and 0.5 parts respectively; the air liberated from charcoal at 85 deg. Cent. absolute contained 1.64 and 0.1 parts, and air from a steel bottle (likewise liberated from charcoal at 85 deg. Cent. absolute), 1.53 and 9.8 parts. Gautier had only found a trace of helium in sea-air.

The question arose in such determinations whether the frozen oxygen and nitrogen did not occlude any other gases. Under ordinary conditions, Sir James stated, they did not, apparently; but when certain mixtures of gases were tested, an occlusion seemed to occur. Thus, all the nitrogen condensed at 20 deg. Cent. absolute under high exhaust could be regained at + 15 deg. Cent.; so could carbon dioxide; but in mixtures of nitrogen, or of carbon dioxide with much hydrogen (20:80), there was some occlusion, though almost all the occluded gas was liberated again at + 15 deg. Cent. Hydrogen and carbon dioxide, therefore, became together volatile when they had formed a solid solution which was more volatile than carbon dioxide, but less volatile than hydrogen. The minimum gas pressure of chemical nitrogen seemed to be $0.33 \cdot 10^{-4}$ millimeter (the usual unit of pressure in Sir James's experiments); but with the aid of the molecular air-pump [of Gaedel the pressure could be reduced to $0.07 \cdot 10^{-4}$ millimeter.

The next series of experiments of Prof. Dewar concerned the permeability of metals (hot or cold), like platinum, palladium iron, and also quartz, to gases. This permeability was a source of trouble. The experiments were so conducted that a tube of platinum, e. g., closed at one end, was evacuated and joined to a discharge tube, which would not allow the discharge to pass as long as the gas pressure was too low. An oil-pressure gage was joined to the apparatus and the time was measured, so that the rate of the rise of pressure could be watched. When the platinum was heated in a gas-burner, the discharge began to pass, because the hot platinum was permeable to the hydrogen in the gas-flame, so that hydrogen entered the platinum tube. When a quartz tube was pushed over the hot platinum tube, so as to form a jacket round it, the manometer went back, because the quartz was not permeable to hydrogen. This was still more striking when the quartz tube was drawn out so as to allow the introduction of different gases into the annular space. The experiments proved that platinum, heated by a Meker burner, was most permeable to some gas (chiefly hydrogen) when placed in the lower part of the flame, where hydrogen predominates; the curves obtained when the tube was in the middle or in the top portion of the flame indicated a smaller rise of pressure, and a less abrupt fall of pressure again when the flame was removed. An iron tube proved permeable to hydrogen, like platinum; in a palladium tube the rise of pressure was, under the same conditions, much more rapid. When carbon monoxide (supplied strongly compressed) was burned in a Bunsen burner with a pale blue flame, no gas (neither the CO, nor the CO_2 produced by the burning of the CO) penetrated through the hot palladium. Experiments were then made with helium; it was demonstrated that helium easily passed through hot quartz, while hydrogen would not diffuse through hot quartz, though it would readily pass through hot platinum.

The permeability of skins or films of rubber 0.01 millimeter in thickness, stretched over a metallic frame, was also demonstrated, and some surprising results were shown. Oxygen passed more readily through a rubber skin than hydrogen and argon more readily than nitrogen, so that rubber would appear to be more permeable to gases of high atomic weight than to gases of low atomic weight. The wet film was much less permeable; and dry air (dried by being bubbled through liquid air) passed more quickly through the dry film than humid air (from the lecture-room). Dipping the film itself into liquid air would make it impermeable; the same impermeability resulted when the rubber was dipped into gylcerin, which could only be done properly with a dry film. Water vapor found its way also through hot palladium and platinum. These various features, the occlusion of gases, the ubiquity of hydrogen, the permeability of metals and rubber, etc., render the investigation of the rare gases still more difficult than it is otherwise. In his researches on respired air Sir James makes his apparatus entirely of glass and metal; rubber connections and greased stop-cocks, which might give off gas, have to be avoided.

* From *Engineering*.

Electrical Conductivity Imparted to Liquid Air by Alpha Rays

In a paper read before the Royal Society of Canada an interesting series of experiments conducted by Prof. J. C. McLellan and Mr. David A. Keys is described. A brief summary of the results is given herewith.

In the published account of their experiments on the measurement of the dielectric constants of different liquefied gases, a number of investigators, including Linde,[1] Dewar and Fleming,[2] and Hasenöhrl,[3] have drawn attention to the high insulating qualities possessed by such liquids. In particular Fleming and Dewar have shown that a small condenser when immersed in liquid air and charged with a Wimshurst electrical machine held its charge perfectly for a period of some minutes. Quite recently, too, Zeeman[4] in studying the Kerr phenomenon in liquid air found when the latter was freed from small ice and carbonic dioxide crystals by filtration, and when precautions were taken to prevent the generation of gas bubbles between the electrodes, electric fields as high as 90,000 volts per centimeter, and even higher ones could be maintained quite readily in the liquid.

Fleming and Dewar in the course of their experiments made a determination of the dielectric constant of liquefied air and also of that of liquid oxygen. The latter they found to be 1.495. If we assume the density of gaseous oxygen at 15 deg. Cent. and 760 millimeters pressure to be 0.00134 (and its density at —182 deg. Cent., consequently to be 0.00424) and its dielectric constant at 0 deg. Cent. and 760 millimeters pressure to be 1.00059, it follows by applying the Clausius Mosotti relation—that K—1 is proportional to the density of the gas—that the dielectric constant of gaseous oxygen at —182 deg. Cent. and 760 millimeters pressure should be approximately 1.0018.

Moreover, as the density of liquid oxygen is about 1.1375, it follows, if we assume the Clausius Mosotti's Law to hold continuously in passing from the gaseous to the liquid phase, that the dielectric constant of liquid oxygen should be approximately 1.4824. This, it will be seen, is very close to the value found by Dewar and Fleming in their experiments.

In view of this continuity in the dielectric property of oxygen in passing through the stage of liquefaction, it was thought to be of interest by the writers to see if any indication of a similar continuity could be obtained in the ionization of air by alpha rays when passing from the gaseous to the liquid state.

The results so far reached may be summed up as follows:

(1) In a number of experiments it has been shown in agreement with a number of other experimenters that liquid air when freshly filtered is an extremely good insulator, and that its conductivity in the absence of any ionizing radiation other than that from the earth is much the same as that of ordinary clean air at atmospheric pressure.

(2) The dielectric constant of liquid air was found to be 1.43.

(3) The saturation current obtained in air at ordinary pressure by the complete absorption of the alpha radiation emitted by a plate coated with polonium was found to be about 16 times the maximum current obtained with the highest fields used when the radiation was absorbed in air at 101 atmospheres and about 576 times the maximum current obtained in liquid air when the ionization was produced by the same radiation.

(4) The mobility of the positive ion produced in air at 116 atmospheres by alpha rays was found to be 0.0005294 centimeter second per volt per centimeter, and that the negative 0.0006217 centimeter second per volt per centimeter, the latter being about 1.18 times the former.

(5) Evidence has been found in the course of the investigation of the existence of a penetrating radiation emitted by the layer of polonium which furnished the alpha rays.

[1] Linde. *Wied. Ann.* 56, p. 546. 1895.

[2] Dewar and Fleming. *Proc. Roy. Soc.*, London. p. 358, vol. 60, 1896.

[3] Hasenöhrl, Leiden. Comm. No. 52. *Proc. Ams. Akad.*, 11, p. 211.

[4] Zeeman, *Proc. Amst. Akad, of Sc.*, January 24th, 1912, p. 850.

NEW BOOKS, ETC.

DIE MATERIE. Von The. Svedberg. Professor an der Universitaet Upsala. Deutsche Ubersetzung von Dr. H. Finkelstein. Leipzig: Akademische Verlagsgesellschaft. m b. H., 1914.

As one reads this extremely interesting and instructive history of the theories of matter, one cannot but be struck by the fact that the conceptions of our latest science are by no means discordant with those that flourished in the days of the ancients. After a certain point is reached in the development of the electronic theory, one necessarily steps across the threshold of science into the realm of metaphysics. When that passage is made, one is startled to find that one is in the company of the Greeks. Books such as that of Prof. Svedberg are always valuable, because they unroll as it were the parchment of the ages, and show how, after all, the most startling and revolutionary and scientific discoveries are but short steps in advance.

IRON NAVY. By Archibald Herz. With a Preface by the Earl of Selborne, K.G. London and New York: Frederick Ward & Co. 1914. 270 pp. Price, 50 cents net.

It has been the endeavor of the author in this volume to sketch briefly the gradual evolution of British sea power, and to trace the course of that recent rivalry in naval armament which has brought the British Empire face to face with a situation of great gravity. The work opens with a chapter on the creation of the navy, and deals with the period from King Alfred, A. D. 872, to Richard III., A. D. 1475. This is followed by chapters on sea power under the Tudors, including the defeat of the Armada; the seventeenth century navy, marking the triumph over the Dutch; Nelson's early victories, Trafalgar, the Victorian Renaissance; the German Navy Act; the Reform Movement of 1904–1912. The final chapters deal with the composition and distribution of the British fleet, manning, the administration of the navy, and the imperial policy.

ROBERT FULTON, ENGINEER AND ARTIST. His Life and Work. By H. W. Dickinson. A.M.I.M.E., Assistant Keeper Science Museum, South Kensington. With numerous plates and several illustrations in the text. London: John Lane, The Bodley Head. New York: John Lane Company. Toronto: Bell & Coster, 1913. 331 pp. Price, $3 net.

Here is a work which does adequate justice to a great man and a great achievement. Although in point of chronology Robert Fulton was an artist first and an engineer afterward, there can be no doubt that in his instinct and sympathies he was first an engineer. Nevertheless, the fact that he was an artist of ability is apt to be overlooked, and in this exhaustive review of his life and work this fact is brought out. Much has been written about Fulton and the "Clermont," but it has been reserved for the assistant keeper of the Science Museum, South Kensington, to gather up and throw into thoroughly collected and readable form all the essential facts related to this subject. The book opens with a sketch of the ancestry, birth and boyhood of Robert Fulton, and speaks of his work as a painter of miniatures, his journey to England, his exhibit at the Royal Academy, and of his turning from the work of an artist to that of a marine engineer and architect. The book tells of his project for marine propulsion, his studies of the English canal system, his digging machine and patent for inclined planes, his correspondence with Lord Stanhope, his arrival in France and his submarine project, and his turning his attention to steam navigation.

This is followed by a sketch of the work of previous experimenters, in which justice is done to the very clever and original work accomplished before Fulton entered the field. Then the story shifts from Paris to England, where Fulton orders a steamboat engine and leaves for the United States. His torpedo experiments are dealt with, and a chapter is devoted to his United States patents, the steamboat monopoly, and the litigation to which it gave rise. The final chapter describes the construction of the first steam man-of-war, and makes reference to the recent Hudson-Fulton celebration. The illustrations are admirable, particularly the reproduction of the original portrait of Fulton by Peale, which is in Independence Hall, Philadelphia, Pa.

HANDBUCH FÜR HEER UND FLOTTE. Enzyklopädie der Kriegswissenschaften und verwandter Gebiete. Herausgegeben von Georg von Alten, Generalleutnant z. D., fortgeführt von Hans von Albert, Hauptmann a. D. Unter Mitwivkung von etwa 400 der bedeutendsten Fachautoritäten. Vollständig in 9 Bänden reichillustrierten Textes mit farbigen Beilagen, Karten, Plänen, Gefechtsskizzen usw. Berlin: Deutsches Verlagshaus Bong & Co., 1914.

These installments of the Handbuch, numbers 69 to 72, are of particular interest to Americans, because they discuss the events in Mexico in a remarkably fine monograph on War (Krieg). The author is General von Falkenhausen. How the army and navy should co-operate is set forth by General von Janson. In the same installments will be found good articles on the "experiences of war," the "war game," and the science of war in general. In view of the present European conflict, one obtains a very good insight into the technical and strategic methods of the Germans in such articles as "*Lager*," "*Landregimenter*," "*Landsknechte*," "*Landsturm*," *and* "*Landwehr*." Interesting and valuable too are the articles on War Treasures and on the House of Krupp. Numerous maps, tables and drawings will be found scattered throughout the text.

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